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Environmental Monitoring of a Wastewater Treatment Plant

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16. ABSTRACT

A wastewater aerosol monitoring program was conducted at an advanced wastewater treatment facility using the activated sludge process. This plant was recently constructed next to an elementary school in Tigard, Oregon. Wastewater aerosols containing pathogenic organisms are generated by the aeration basin (within 400 meters of the classroom area) and by an aerated surge basin (within 50 meters of the school playground). From a preliminary microbial screen of the wastewater, predominant indicator and pathogenic microorganisms were selected for routine wastewater and aerosol monitoring. The geometric mean aerosol concentrations at 30 to 50 meters downwind of the aeration basin were 5.8 cfu/m^3 of total coliforms, 2.0 cfu/m^3 of fecal streptococci, 9.1 cfu/m^3 of mycobacteria, 7 cfu/m^3 of Pseudomonas, 0.7 pfu/m^3 of coliphage, and <0.0009 pfu/m^3 of enteroviruses. The inability to detect enteroviruses in air resulted from their low concentration (relative to other test organisms) in the wastewater and from their adsorption onto and incorporation into the mixed liquor suspended solids which are not easily aerosolized.

While it is a relatively insensitive measure, attendance at the nearby school and eight control schools provided no evidence of adverse effects from wastewater treatment plant operation. If any adverse effects had occurred, it was slight enough to be completely obscured by the usual school absenteeism factors.

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ENVIRONMENTAL MONITORING OF A WASTEWATER TREATMENT PLANT

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DISCLAIMER

This report has been reviewed by the Health Effects Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The primary mission of the Health Effects Research Laboratory in Cincinnati (HERL) is to provide a sound health effects data base in support of the regulatory activities of the EPA. To this end, HERL conducts a research program to identify, characterize, and quantitate harmful effects of pollutants that may result from exposure to chemical, physical, or biological agents found in the environment. In addition to valuable health information generated by these activities, new research techniques and methods are being developed that contribute to a better understanding of human biochemical and physiological functions, and how these functions are altered by low-level insults.

This report provides data on microorganisms in aerosols from a wastewater treatment plant and discusses student absenteeism at a nearby school. With a better understanding of the health effects, measures can be developed to reduce exposure to potentially harmful materials.

R. J. Garner
Director
Health Effects Research Laboratory

ABSTRACT

A wastewater aerosol monitoring program was conducted at an advanced wastewater treatment facility using the activated sludge process. This plant was recently constructed next to an elementary school in Tigard, Oregon. Wastewater aerosols containing pathogenic organisms are generated by the aeration basin (within 400 meters of the classroom area) and by an aerated surge basin (within 50 meters of the school playground). From a preliminary microbial screen of the wastewater, predominant indicator and pathogenic microorganisms were selected for routine wastewater and aerosol monitoring.

The aeration basin was observed to be a much stronger source of aerosolized microorganisms than the surge basin. The geometric mean aerosol concentrations at 30 to 50 meters downwind of the aeration basin were 5.8 cfu/m^3 of total coliforms, 2.0 cfu/m^3 of fecal streptococci, 9.1 cfu/m^3 of mycobacteria, 7 cfu/m^3 of Pseudomonas, 0.7 pfu/m^3 of coliphage, and <0.0009 pfu/m^3 of enteroviruses. Mycobacteria were found to be more prevalent at this plant than at previously monitored sites. The inability to detect enteroviruses in air resulted from their low concentration (relative to other test organisms) in the wastewater and from their adsorption onto and incorporation into the mixed liquor suspended solids which are not easily aerosolized.

While it is a relatively insensitive measure, attendance at the nearby school and eight control schools provided no evidence of adverse effects from wastewater treatment plant operation. In fact, attendance at the nearby school generally improved after sewage treatment commenced. If any adverse effect had occurred, it was slight enough to be completely obscured by the usual school absenteeism factors. The students probably received a peak daily dose of about 9 cfu of mycobacteria and 3.5 cfu of fecal streptococci about one school day per year, which may only be 100 to 1000 times the usual outdoor background dose.

This report was submitted in fulfillment of Grant R-805533 by Southwest Research Institute under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from October 1977 to March 1978, and work was completed as of March 1979.

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SECTION 1

INTRODUCTION

BACKGROUND

Through its program of construction grants to states and municipalities, the Environmental Protection Agency (EPA) is sponsoring a multimillion dollar effort to construct new wastewater treatment facilties throughout the United States. These facilities are necessary to comply with federal regulations regarding the discharge of wastes into rivers, lakes and oceans. The EPA also provides technical assistance to the grant recipient regarding the design and location of the wastewater treatment facilities.

In the past, many wastewater treatment facilities were located away from residential areas, usually due to aesthetic considerations. With urban development, the buffer zones around many of the older facilities have been used as residential areas. There has also been a need for construction of new facilities and for optimal engineering design. The treatment facilities need to be located as near as possible to the populations they serve in order to minimize transit times of wastes. The location of wastewater treatment facilities near populated areas may pose problems of odors, noise, and possibly adverse health effects. Odor and noise are engineering problems which can be controlled in a well operated plant.

A common technique for secondary treatment of wastewater is the activated sludge treatment process which requires that the incoming wastewater be aerated in an aeration basin in the biological treatment process. Aerosols are formed at the surface of the wastewater in the aeration basin. The wastewater in the aeration basin contains numerous bacteria and viruses because, at most, only primary treatment, involving removal of large solids, has occurred. Microorganisms in the wastewater aerosols might be carried by the wind into nearby residential areas and initiate infection.

Two environmental epidemiology studies have recently been performed to investigate possible health effects to populations living near large activated sludge treatment facilities. Carnow, et al.[1] examined an older plant [operating level of 290 million gallons per day (MGD) with 400 MGD capacity] in Skokie, Illinois, while Johnson, et al.[2] studied a new plant, with an initial operating level of 15 to 20 MGD (with 30 MGD capacity) located near Schaumburg, Illinois. In both studies, the levels of microorganisms in the wastewater at the plant and in aerosols emanating from the plant were measured to determine microorganism transport into populated areas. In both studies, measures of the health of the people living near the plant were compared to those of matched populations living farther away from the plant. Various respiratory and gastrointestinal infectious diseases that might be associated with exposure to aerosols containing microorganisms from the waste treatment plant were examined. The incidence of symptoms was obtained at regular intervals through questionnaires, while direct evidence of infection was being sought through clinical specimens (blood, feces, throat swab, etc.) from participants. This information was then statistically evaluated for the prevalence of symptoms, diseases, and evidence of infection relative to distance of the residences from the treatment plant. In general, both studies found little evidence of detectable health effects. This may be because both studies lacked enough participants living very close to the sources of the aerosol (who would have substantial exposure from the aerosol). In the study by Johnson et al., the requirement for evaluating a new plant necessitated examining an area that was sparsely populated. In the study by Carnow et al., industries occupied much of the area near the treatment plant, so that few residences were located near the plant.

The present study has been conducted at the Durham Advanced Wastewater Treatment Plant (DAWTP) in Tigard, Oregon (near Portland), which is located immediately adjacent to Durham Elementary School. While operating at 9 to 13 MGD during the study period, this activated sludge plant has a current capacity of approximately 20 MGD which can be expanded to 60 MGD.

The Unified Sewerage Agency which operates the DAWTP has received frequent complaints of noise and odor problems which it has tried to rectify.

RATIONALE FOR THE STUDY

There has been concern among public health organizations that the operation of the DAWTP so near the Durham Elementary School might cause some health problems among the school children. (The school playground extends to within 50 meters of the nearest aerator in a surge basin, while the school buildings are only about 250 meters from the aerated surge basin and 400 meters from the aeration basin.) This study was initiated to collect environmental data regarding the type and quantities of microorganisms emitted from the waste treatment facility and to determine the types and quantities that are transported into the environment of the school. A smaller portion of the study was to examine school attendance in order to make a preliminary evaluation of possible health effects.

While the two studies described above provide information about health effects of large activated-sludge treatment facilities, there were few persons living very close to the treatment facility. The DAWTP and elementary school provide a unique health effects study site in that a population of young children spend a large portion of their active time (approximately 35 hours per week for nine months of the year) within a quarter of a mile of an activated sludge plant's aerosol source.

STUDY OBJECTIVES

One objective of this study was to measure the types and quantities of viable microorganisms present in the ambient air upwind and up to 100 meters downwind of the DAWTP. Measurement of microorganisms was also to be in the wastewater at the aerosol sources in the plant, including the aeration basin and the aerated surge basin. This portion of the effort was to ascertain the levels and types of microorganisms present in the wastewater which were available for aerosolization.

A second objective of this study was to determine whether the absentee rate at Durham Elementary School was significantly different from the absentee rates at control schools located in the same area but not near a wastewater treatment facility. This would provide some preliminary indication of possible health effects which might be associated with the treatment facility.

STUDY DESIGN

The first phase of environmental monitoring involved the collection of large samples of wastewater from each potential source of aerosolized microorganisms at the plant: the aeration basins, the aerated surge basin, and the secondary recarbonation basin. A microbial screen of wastewater samples from each of these unit processes was conducted to characterize the type and approximate concentration of viruses and a variety of enteric bacteria. These results were used to select the types of organisms and methods to be used during the routine monitoring of wastewater and aerosols in the second phase. In addition, the relative levels of various test organisms present in the different aerosol sources in the plant were compared to choose the source or sources about which to conduct the major portion of the aerosol sampling.

During the second phase of environmental monitoring, six aerosol runs were conducted to simultaneously measure levels of microorganisms in wastewater and air at the aeration basin and surge basin. A special enterovirus aerosol run was also conducted to measure enterovirus levels at the aeration basin. The level and frequency of microbial aerosols reaching the school were estimated.

Eight suitable control schools for Durham Elementary were selected. Quarterly attendance data for the nine schools were obtained for the seven school years prior to DAWTP operation and for the first two school years of DAWTP operation. If the DAWTP had an adverse health effect, one would expect to see high absenteeism at Durham Elementary (relative to the control schools) in the two operational years. Such absenteeism might take the form of a uniformly higher absence rate throughout the two operational years, or because of acquired immunity, it might only be evident during the first several months of aerosol exposure episodes.

PARTICIPATING ORGANIZATIONS AND PRINCIPAL PERSONNEL

The research effort described in this report has been performed by Southwest Research Institute with significant support and contributions from several other organizations. The following is a list of these participating organizations:

Southwest Research Institute (SwRI), San Antonio, Texas
The University of Texas at San Antonio (UTSA), San Antonio, Texas
Naval Biosciences Laboratory (NBL), Oakland, California
Tigard Public Schools, Tigard, Oregon
Durham Elementary School, Tigard, Oregon
Lake Oswego Public Schools, Lake Oswego, Oregon
Department of Environmental Quality, Portland, Oregon
Unified Sewerage Agency, Hillsborough, Oregon
Durham Advanced Wastewater Treatment Plant, Tigard, Oregon
Dr. Robert Northrop, University of Illinois, Chicago, Illinois

The principal participating personnel and their areas of responsibility are shown below:

SwRI Department of Environmental Sciences

D. E. Johnson, Ph.D.	Principal Investigator
H. J. Harding	Direction of Field Activities
D. E. Camann	Statistician

UTSA Center for Applied Research and Technology

C. A. Sorber, Ph.D.	Direction of Analysis
B. E. Moore	Sample Analysis

NBL

M. A. Chatigny	Consultant in Aerobiology and loan of aerosol samplers

SECTION 2

CONCLUSIONS

The aeration basin was found to be a much stronger source of aerosolized microorganisms than was the aerated surge basin at the Durham Advanced Wastewater Treatment Plant (DAWTP).

The geometric mean aerosol concentrations at 30 to 50 meters downwind of the aeration basin were 5.8 cfu/m^3 of total coliforms, 2.0 cfu/m^3 of fecal streptococci, 9.1 cfu/m^3 of mycobacteria, 7 cfu/m^3 of *Pseudomonas*, and 0.7 pfu/m^3 of coliphage. Mycobacteria were observed to be more prevalent at the DAWTP than at other wastewater aerosol monitoring sites.

Enteroviruses were not detected in the air 30 meters downwind of the aeration basin (<0.0009 pfu/m^3). This resulted from their low concentration (relative to other test organisms) in the wastewater and from the association of 98 percent of the wastewater enteroviruses with solid matter (i.e., mixed liquor suspended solids in the aeration basin) which is not readily aerosolized.

No adverse effects of DAWTP operation were detected in the Durham Elementary attendance data. In fact, school attendance generally improved after sewage treatment commenced. If any adverse effect had occurred, it was so slight as to be completely obscured by the usual factors affecting school absenteeism.

The Durham students probably received a peak daily dose of about 9 cfu of mycobacteria and 3.5 cfu of fecal streptococci about one school day per year. These exceed the usual outdoor background doses by perhaps three or more orders of magnitude for mycobacteria and by about two orders of magnitude for fecal streptococci. At this dose and frequency, a rather insensitive measure, school attendance, provided no evidence of an adverse health response.

SECTION 3

RECOMMENDATIONS

Dose-response relationships need to be developed for the pathogenic microorganisms prevalent in wastewater aerosols so that the health hazards of monitored sources can be more adequately assessed. To obtain some data points along a dose-response relationship, an estimated exposure dose should be reported along with the health response results of an epidemiologic investigation whenever possible. Imprecise estimates of peak exposure to prevalent pathogens can be predicted from aerosol monitoring, mathematical models, and historical wind direction data, as was done in this study.

No further epidemiological investigation of health effects around the DAWTP should be conducted at this time.

SECTION 4

STUDY SITE

DURHAM ADVANCED WASTEWATER TREATMENT PLANT (DAWTP)

Plant Description

Design and Initial Operations--

In 1970 the residents of Washington County, an area at the southwestern edge of the rapidly growing Portland, Oregon metropolitan area, established the Unified Sewerage Agency of Washington County (USA) in an attempt to end the fragmented approach to wastewater management that had occurred in the past. Using a master plan proposed by the consulting firm of Stevens, Thompson and Runyan, USA embarked on a pollution control program which called for elimination of all treatment plants on the tributaries of the Tualatin River and construction or expansion of four major treatment facilities along the river.

The largest of the new facilities is the Durham Advanced Wastewater Treatment Plant (DAWTP). This plant is situated next to Fanno Creek, a tributary of the Tualatin River, in an area which has recently (Fall 1978) been annexed by the City of Tigard. The DAWTP services the entire Fanno Creek drainage basin and nearby areas. Figure 1 shows the location of the plant and the area served. The DAWTP commenced operation on July 6, 1976 with an initial design capacity of 75,000 cubic meters per day (20 MGD) that can be expanded to 227,000 cubic meters per day (60 MGD) by the year 2000 to meet the needs of this rapidly growing area.

Designed as a modern activated sludge plant incorporating some advanced processes for wastewater treatment, the DAWTP is comprised of two parallel plants which can be operated separately from primary clarification to the point of effluent discharge. Alternatively, flows can be combined from the separate plants after various stages of treatment. All plant influent first passes through barminutors to screen out and reduce the size of large objects. The flow is then divided and sent to two primary clarifiers in parallel where settleable solids and grit are removed. Secondary treatment begins with the classical activated sludge process in four aeration tanks.

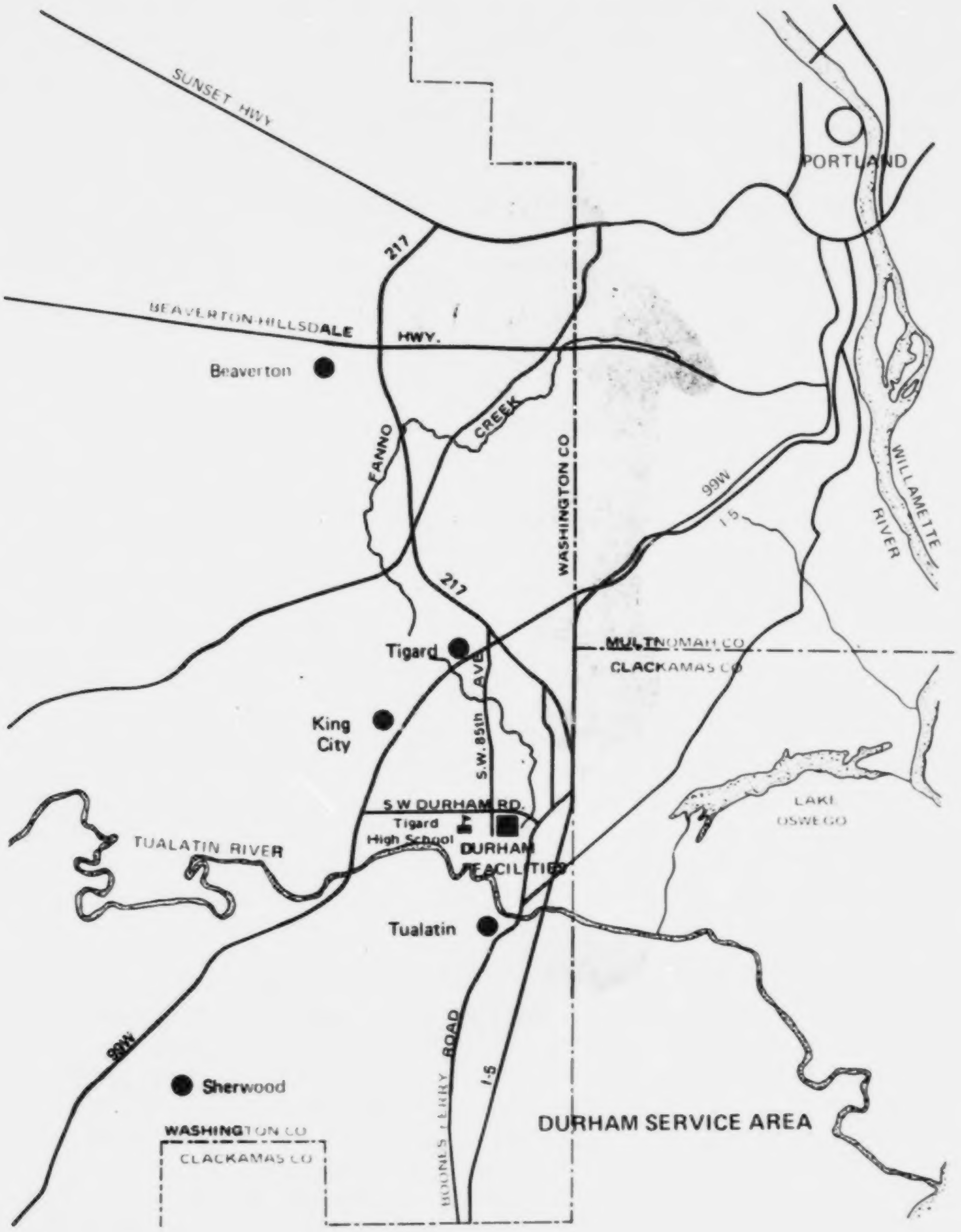


Figure 1. Durham Service Area

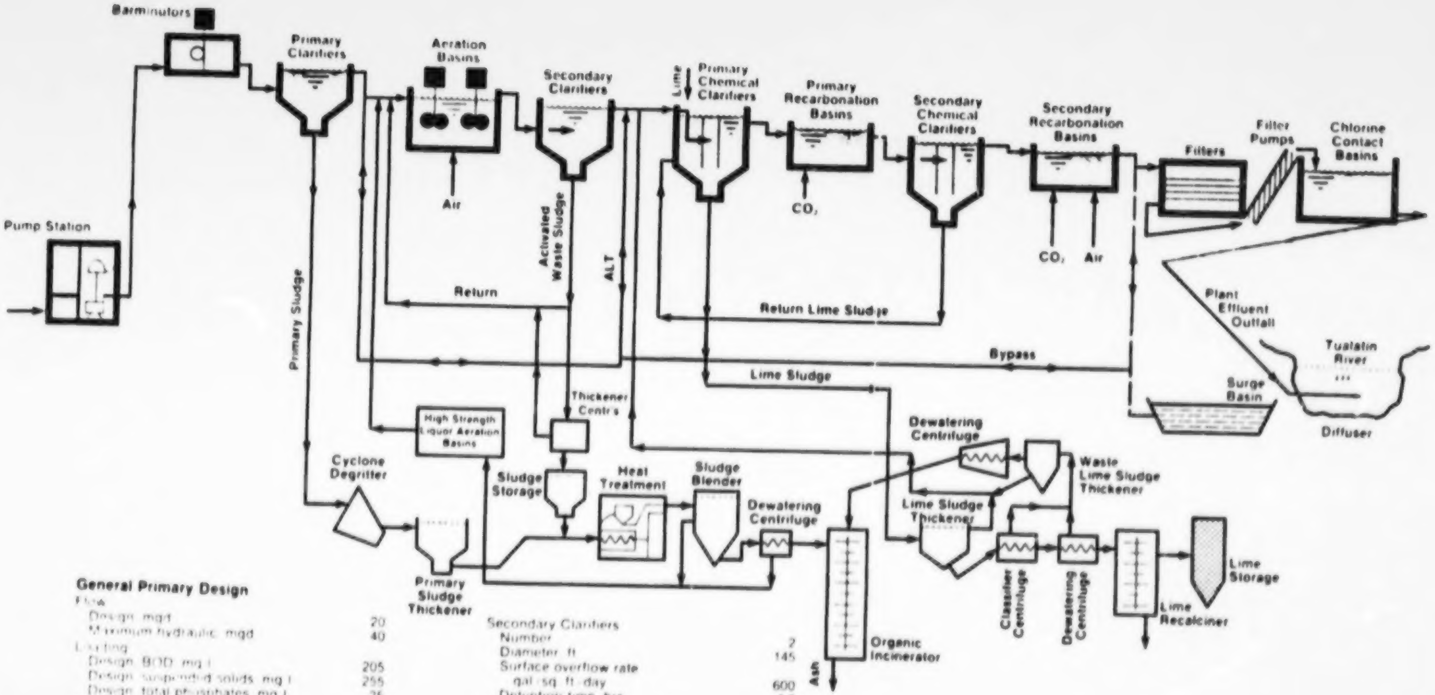
After secondary clarification, the wastewater is subjected to advanced wastewater treatment processes for reduction of phosphorus and solids. These processes are a critical part of the treatment from May to November when the Tualatin has its lowest flows. In early operation, lime slurry was mixed with the wastewater followed by secondary recarbonation to reduce pH and remove excess lime. The lime sludge was thickened, dewatered and recalcined for recycling in this treatment process. However, the rapidly escalating cost of energy and mechanical problems with this system resulted in the abandonment of lime in favor of alum treatment and coagulant aids. Plant effluent is then filtered and chlorinated prior to discharge in the Tualatin River. Organic sludge from the primary and secondary clarifiers is processed in a series of gravity sludge thickeners, cyclone-type grit separators, disc centrifuges and continuous bowl centrifuges. After heat treatment and incineration the resulting ash is used for land fill. A schematic flow diagram of plant processes is shown in Figure 2.

The efficient operation of activated sludge, chemical coagulation, and filtration systems requires that hydraulic load be as constant as possible. This is a problem in the Portland area because of the high annual rainfall [averaging 97 cm (38 inches) per year] and the ever-present infiltration. To accommodate plant flow during periods of extensive rainfall, two large surge basins were built adjacent to the plant. The larger surge basin has a capacity of 38,000 cubic meters (10 million gallons), while the other has a capacity of 19,000 cubic meters (5 million gallons). A small basin of 7,600 cubic meters (2 million gallons) capacity is situated adjacent to the surge basins and has no surface aeration. Its purpose is to catch backwash from the filters. Flow from any of the plant processes can be diverted to the surge basins, but typically, primary clarifier effluent is diverted to these basins in sufficient quantity to maintain a relatively constant flow through the activated sludge process. Three surface aerators in the second largest surge basin (No. 1 surge basin) prevent the primary treated wastewater from becoming anaerobic. During periods of low influent flow, wastewater from the surge basin can be reintroduced into the secondary treatment process to equalize flow through the secondary and tertiary treatment sections of the plant.

Microbial Aerosol Sources During Sampling Periods--

The production and transport of microbial aerosols of pathogenic organisms were the primary health concerns investigated in this study. At the time the original scope of work was proposed, it was determined that there were three potential sources of aerosol formation within the DAWTP: the aeration basins, the surge basins, and the secondary recarbonation basin.

However, during the two periods of sample collection (November 1977 and March 1978) two major changes in the operation of the plant significantly changed the production of aerosols. No chemical treatment (including recarbonation) was performed during either of the sample periods. This eliminated the secondary recarbonation basin as a source of aerosol.



General Primary Design

Flow	
Design mgd	20
Maximum hydraulic mgd	40
Loading	
Design BOD mg l	205
Design suspended solids mg l	255
Design total phosphates mg l	25
Pump Station	
2 Variable speed pumps gpm each	12 200
2 Fixed speed pumps gpm each	8 300
Primary Clarifiers	
Number	2
Diameter ft	120
Surface overflow rate gal sq ft day	880
Detention time hrs	2 4
Primary Sludge Thickeners	
Number	1
Diameter ft	50
Solids loading lbs sq ft day	14

General Secondary Design

Aeration Tanks	
Number	4
Water depth ft	20
Volume cu ft each	142 000
Loading lbs BOD day lb MLSS	0 35
Detention time hrs	5 1
Secondary Clarifiers	
Number	2
Diameter ft	145
Surface overflow rate gal sq ft day	600
Detention time hrs	4 2
Return Activated Sludge Pumps	
Number	2
Rated capacity gpm each	10 500
mgd each	15
Lime Sludge Thickeners	
Number	2
Diameter ft	50
Sludge Heat Treatment (Secondary Only)	
Number of systems	2
Capacity gpd 1 @	96 000
1 @	24 000
Sludge Dewatering	
Type	centrifuge
Number	4
Total rated capacity lbs hr	5000
Sludge Incinerator	
Number	1
Capacity lbs hr	2000
Lime Recalcining	
Centrifuges	1
Capacity lbs /hr	5000
Recalciner	1
Capacity lbs /hr	5500
Chlorination	
Number	4
Capacity lbs 24 hrs	32 000
Chlorine contact time	
Design hr	1
Peak hr	0 5

General Advanced Treatment

Primary & Secondary Chemical Clarifiers	
Number primary	2
secondary	2
Size each	100 ft sq
Detention time hrs	2 8
Primary & Secondary Recarbonation Basins	
Number primary	2
Detention time hrs	0 33
Number secondary	2
Detention time hrs	0 6
Filtration System	
Number	4
Type	mixed media
Area sq ft each	900
Rate gpm/sq ft	3 9

Figure 2. Durham Advanced Wastewater Treatment Plant Processes

Also, through extensive experimentation with process parameters, plant personnel determined that use of a single aeration basin resulted in optimal operation of the activated sludge process. In this mode of operation, all wastewater is mixed with activated sludge in a 3,800 cubic meter (1 million gallon) capacity aeration basin with a detention time of 1.5 to 2 hours. Air at a pressure of 0.39 to 0.53 kg/cm^2 (5.5-7.5 psi) is introduced through a 10-cm (four-inch) diameter nozzle located 1.5 m (5 feet) from the bottom of the basin.

Each nozzle is oriented vertically upward underneath a variable speed turbine aerator that agitates the aeration basin liquor and disperses the air stream from the nozzle. There are two nozzle mixer systems in each 21 x 30 x 6 m deep (69 x 100 x 20 feet) aeration basin. Based on the surface area of the aeration basins, perhaps one fourth of the potential aerosol was being generated, since only one of the four aeration basins was being utilized for secondary treatment during the monitoring period.

The third source of aerosol generation, surface aerators on the No. 1 surge basin, was functional during both sampling periods. When the wastewater characterization samples were collected in November 1977, the No. 1 surge basin was being used to return surge to the aeration basin. A total of 12,200 cubic meters (3.22 million gallons) were returned to the aeration basins during 19 hours of the 24-hour operating day commencing at midnight November 9. During the aerosol study in March 1978, the depth of the only aerated surge basin (No. 1) remained constant at 4 m (13 feet) since no wastewater was diverted to or removed from it.

Plant Personnel--

The following personnel of USA were involved in the management of various aspects of plant operations at DAWTP and supervision of the District Laboratory at the time of the study:

DAWTP

Michael B. Mathews	Manager of Operations
Don Dietz	Operations Supervisor
Donna Heppell	Lab Supervisor

USA

Jim West	Director of Water Quality Labs
Jan Miller	District Lab Supervisor

The USA District Laboratory, located at the Durham plant, serves the water quality needs of the USA service area by monitoring plants and analyzing industrial discharges.

Plant Data During Monitoring Periods

Daily data reported by the DAWTP to characterize its operation are presented in Table 1 for both sampling periods. While the DAWTP characterizes the primary influent and the plant effluent, no measurements are made on the plant influent. However, since the primary influent sampling point is between the barminutors and the primary clarifiers (see Figure 2), the primary influent is practically the same as the plant influent.

STUDY SCHOOLS

A map showing the locations of the study school (Durham Elementary), the control schools, and the Durham Advanced Wastewater Treatment Plant (DAWTP) is presented in Figure 3. The locations and areas recently served by Durham Elementary and the control schools in the Tigard School District are provided on the district boundary map in Figure 4.

Durham Elementary School

The school attendance portion of the study focuses on Durham Elementary School, which is located next to the Durham Advanced Wastewater Treatment Plant (see Figure 5). The school building is about 400 meters northeast of the plant's aeration basin and about 200 meters north of the plant's aerated surge basins. The school playground, which is situated between the surge basins and the classrooms, extends to within 10 meters of the plant property and to within 50 meters of the closest aerator in a nearby surge basin.

Durham Elementary is a small six classroom school (one room for each grade level, one through six) belonging to the Tigard School District. It is located in a formerly rural area which is now in the surburban belt around Portland. Durham Elementary was built in 1920 and had a wing of classrooms added around 1960. Since the school has no air conditioning or forced air system, the windows are opened to provide ventilation for cooling and air circulation. During the period studied (September 1969 through June 1978), Durham Elementary has had very little teacher turnover, with the exception of two principal changes in July 1974 and July 1976. The end-of-year enrollment in June 1978 was 123 students. Generally, about 60 percent of the enrolled students attend all six grades at Durham Elementary. Nearly all of the students are white. Forty to forty-five percent of them live in apartments. The students' homes reflect a standard of living in the middle to upper-middle income bracket.

Control Elementary Schools

In order to assess the potential health hazard of the DAWTP as reflected in school attendance at the nearby Durham Elementary School, elementary schools not located near the sewage treatment plant were sought for use as

TABLE 1. DAWTP PLANT DATA DURING DAYS OF MONITORING[a]

	Primary Influent[b]			Plant Effluent			
Date	BOD (mg/L)	Suspended Solids (mg/L)	pH Ave.	Flow (MGD)	BOD (mg/L)	Suspended Solids (mg/L)	pH Ave.
First Sampling Period							
11-8-77	802	662	6.7	9.12	8.9	17.2	6.0
11-9-77	405	803	6.6	11.15	7.3	20.1	---
Nov. 77 Ave.	291	602	6.5	13.33	7.6	24.3	6.1
Second Sampling Period							
3-6-78	162	262	7.0	10.05	18.0	11.4	7.1
3-7-78	115	234	7.2	12.27	21.1	8.8	7.0
3-8-78	132	201	7.1	11.49	16.8	10.1	7.1
3-9-78	95	222	7.1	12.33	14.3	8.9	7.1
3-10-78	112	187	7.1	9.51	10.6	7.4	7.0
3-11-78	98	190	7.1	11.53	11.0	5.0	7.0
3-12-78	140	162	7.2	8.85	5.7	4.2	7.1
Mar. 78 Ave.	134	229	7.1	10.62	13.4	7.7	7.0

[a] Analyses of 24-hour time-composite samples.

[b] Since primary influent is sampled between the barminutors and the primary clarifiers, it is practically the same as the plant influent.

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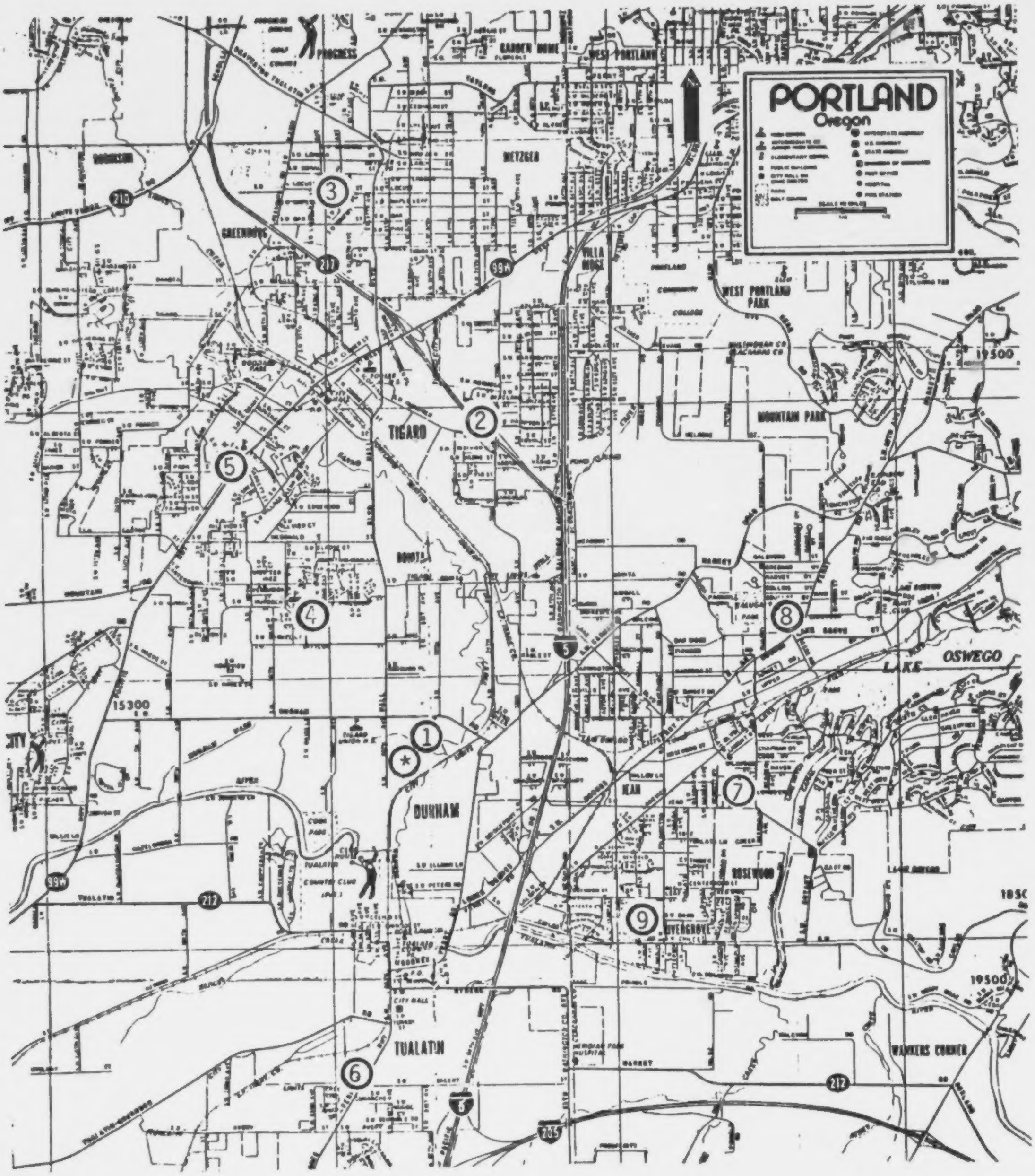


Legend

* Durham Advanced Wastewater Treatment Plant

1 Durham Elem. School
2 Lewis Elem. School
3 Metzger Elem. School
4 Templeton Elem. School

5 Tigard Elem. School
6 Tualatin Elem. School
7 Byrant Elem. School
8 Lake Grove Elem. School
9 River Grove Elem. School

Figure 3. Map of Study Area

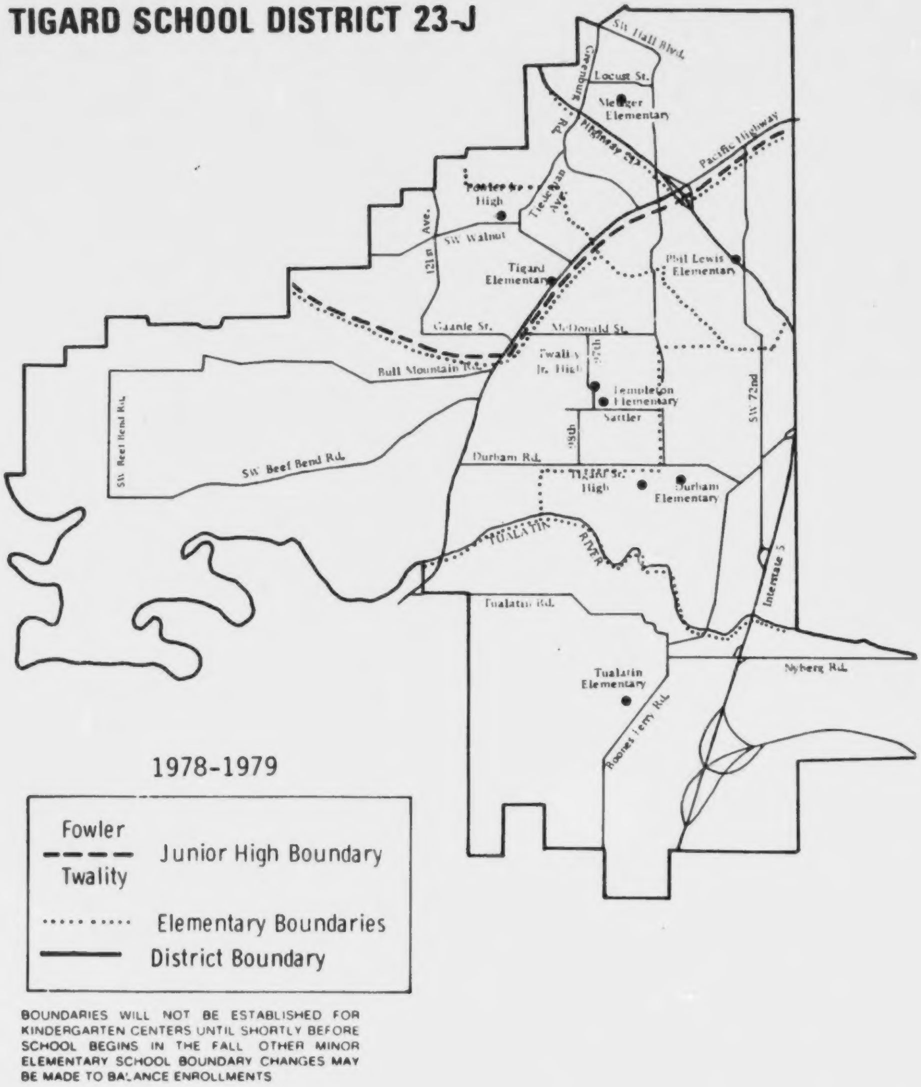


Figure 4. Map of Tigard School District and District Boundaries

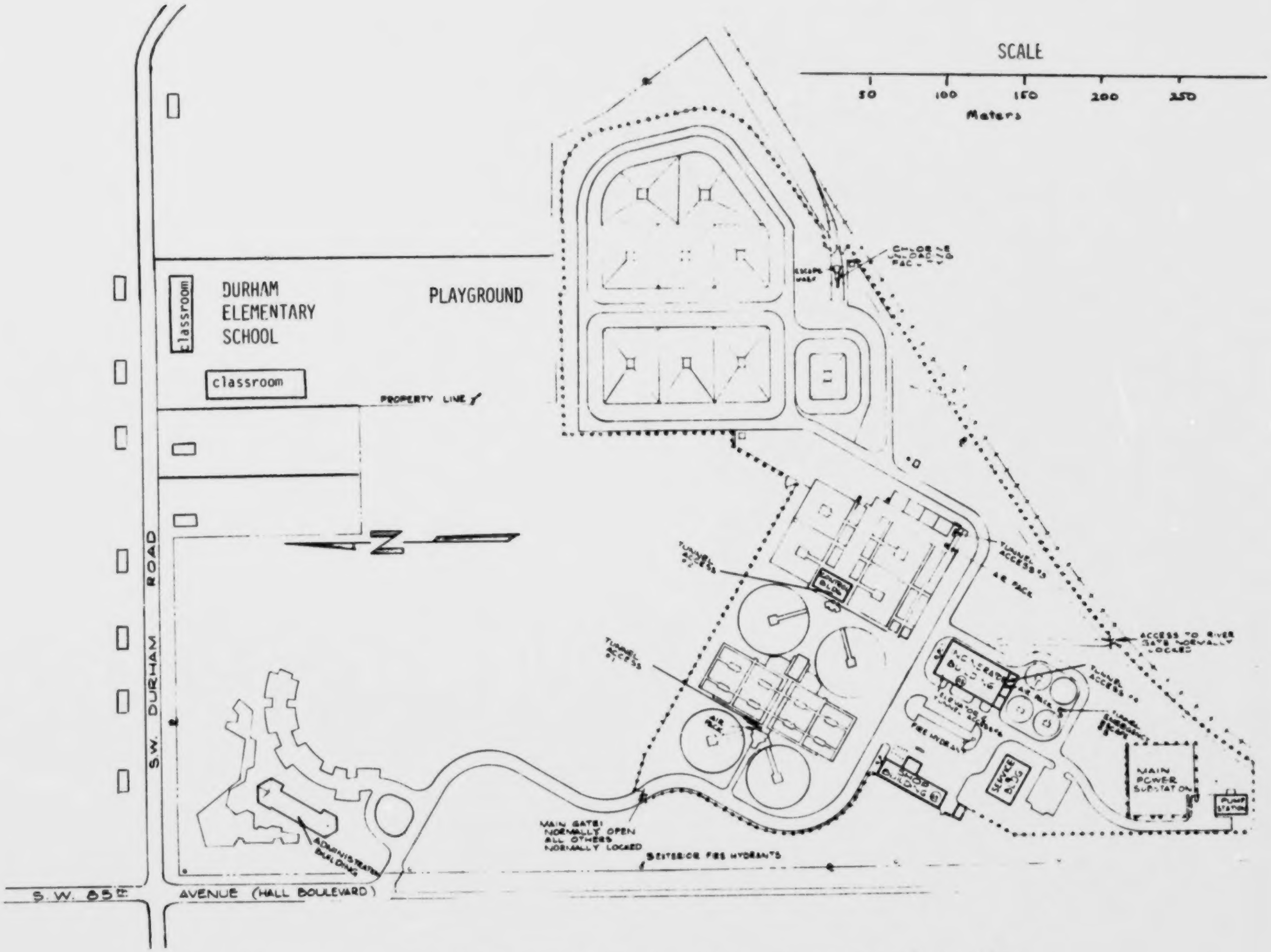


Figure 5. The Proximity of Durham Elementary School to the Durham Wastewater Treatment Facility

controls for Durham Elementary. The demographic characteristics (such as age, sex, color, and ethnic group distributions), attendance records, socioeconomic status, and degree of urbanization of the control schools should be comparable to Durham Elementary. Such controls should provide expected absenteeism rates which take into consideration all relevant factors except exposure to wastewater aerosols. Since absenteeism and health are influenced by the degree of urbanization, one should strive for the same rural-suburban mix in the control schools as in the Durham Elementary service area. Absenteeism is also an attitudinal function; thus, the similarity of attitudes taken by teachers, administrators and parents toward attendance should also be taken into consideration in the selection of control schools.

Based on the above criteria, the remaining five elementary schools in the Tigard School District and the three closest elementary schools in the adjoining Lake Oswego School District were selected as controls for Durham Elementary.

Besides Durham Elementary, the following elementary schools comprise the Tigard School District: Phil Lewis Elementary, Metzger Elementary, James Templeton Elementary, Charles F. Tigard Elementary, and Tualatin Elementary. The three elementary schools selected as controls from the Lake Oswego School District were Bryant Elementary, Lake Grove Elementary and River Grove Elementary.

General Characteristics of Schools

The students attending all the schools are predominantly white, with less than one percent black and Indian and approximately one percent oriental. All are located in the southwest suburbs of Portland. Since 1968, all schools have had a very stable state-wide attendance reporting and monitoring system.

The Tigard School District has had the same attendance administrator since 1965. Of the students in this district, 11 percent to 12 percent live in apartments and 75 percent to 80 percent ride buses to school. On the average, new homes in the district were selling in the $55,000 to $70,000 range during the 1977-78 school year.

Specific characteristics of the schools included in the attendance study are summarized in Table 2. The table characterizes the elementary schools (grades one through six) by school district; by when kindergarten was taught between 1969 and 1978; by their respective distance and direction from the Durham plant aeration basins; by their respective end-of-year enrollment in June 1978; by type of ventilation system used at each school; by the proportion of students living in apartments at each elementary school; and by socioeconomic status, using students' homes to reflect

TABLE 2. BACKGROUND INFORMATION ON SCHOOLS IN SCHOOL ATTENDANCE STUDY

Elementary School (Grades 1-6)	Kindergarten Taught Between 1969 and 1978?	Distance and Direction from Durham Plant Aeration Basins: Distance, Km.	Distance and Direction from Durham Plant Aeration Basins: Direction	End of Year Enrollment (June 1978)	School Ventilation System	Students Living in Apartments	Socio-Economic Status[a]
Tigard School District							
Durham	Never	0.4	NE	123	Open Windows[b]	40%-45% (Many)	M-UM
Lewis	Recent years (1974-78)	3.1	NNE	282	Combination[c]	Many	LM-M
Metzger	Recent years (1974-78)	5.0	N	426	Combination	Few	L-M
Templeton	Never	1.6	NNW	556	Forced Air[d]	Few	M-UM
Tigard	Recent years (1975-78)	3.0	NNW	648	Combination	Few	L-UM
Tualatin	Recent years (1974-78)	2.8	S	566	Combination	Many	M-UM
Lake Oswego School District							
Bryant	Early years	3.1	E	530	Combination	Few	M-UM
Lake Grove	Recent years	3.7	ENE	400	Open Windows	Few	M-UM
River Grove	Never	2.5	SE	308	Combinaton	None	M-UM

[a] Socioeconomic Status Categories, based on value of home

L - Lower class
LM - Lower - middle
M - Middle class
UM - Upper - middle

[b] Open Windows - The windows are opened to provide ventilation for cooling and air circulation.

[c] Combination - Schools having forced air system but often using open windows.

[d] Forced Air - Fans are used to force fresh air through the ventilation system.

the standard of living. For example, Phil Lewis Elementary School is located 3.1 kilometers north-northeast of the Durham plant aeration basins. Since the school is not air conditioned, fans are used to force fresh air into the ventilation system or the windows are opened to provide ventilation for cooling and air circulation. Since the fall of 1974, Lewis Elementary has conducted kindergarten classes every year. Enrollment in grades one through six in June 1978 was 366 students. Many of these students live in apartments. The students' homes reflect a standard of living in the lower-middle to middle income bracket.

Tigard School District has offered kindergarten classes to all children in the district since September 1974. Since not all six elementary schools have had adequate space, the main kindergarten classroom centers have been at Phil Lewis, Metzger, and Tigard Elementary Schools. Children were bussed to the nearest kindergarten center with available space for their kindergarten year, but for the following year, they returned to their area elementary school for their first grade experience.

While Durham Elementary appears to be similar to the control schools in most aspects that are relevant to school attendance, there are some distinct differences between Durham Elementary and the control schools. Durham Elementary students live in a more rural area than those from any control school, except perhaps River Grove Elementary. The number of students attending Durham Elementary is considerably less than at any of the control schools. With the exceptions of Phil Lewis Elementary and Tualatin Elementary, Durham Elementary has a higher proportion of its students dwelling in apartments than any control school. Lastly, Durham Elementary has never had a kindergarten level classroom within its school. Many control schools, however, have either had or recently added or discontinued the kindergarten level. Thus, kindergarten has not been constant from year to year or school to school.

SECTION 5

METHODS AND MATERIALS

SAMPLE COLLECTION AND HANDLING METHODS

Meteorological Measurements and Instrumentation

Simultaneous meteorological measurements were made and recorded continuously at two- and ten-meter heights in the vicinity of the aeration basin during the aerosol sampling period. Location of these towers is indicated on the aerosol run reports (see Appendix F). The following parameters were measured at the two-meter level: wind run and direction, temperature, and relative humidity. The following parameters were measured at the ten-meter level: wind run and direction and temperature. Atmospheric stability can be inferred from the variation in wind direction. Wind velocities assist in determining the probable downwind and crosswind axes of the aerosol plume.

Measurements were made and recorded on time-referenced strip charts by mechanical weather stations manufactured by Meteorology Research, Inc. (MRI). A guyed crank-up tower held the ten-meter level station whereas the two-meter station was located on a rigid tripod. This arrangement permitted easy access to the instrumentation for servicing and chart changing.

Starting threshold for both the anemometer and wind vane is less than three-fourths of a mile per hour. Wind direction measurement accuracy is ±1 percent of full scale while wind speed data are accurate to ±2 percent. Humidity measurements are accurate to ±3 percent over the entire range of humidities from 0 to 100 percent. Temperature measurements are accurate to ±3°F absolute.

Wind direction was determined from the MRI strip charts on an average basis for the two 15-minute periods comprising the aerosol run. An average wind speed for each aerosol run was derived from the recorded wind run during that period.

Supplemental wind speed and direction measurements were obtained from meteorological equipment at DAWTP. The sensors for this information were located 12 meters above ground level on top of the incineration building with the approximate position located on the aerosol run reports (Appendix F). These parameters were recorded on a 10-inch strip chart which provided greater resolution than the MRI instrumentation. Data from both sets of instrumentation are reported.

Field measurements of solar radiation were recorded by a Belfort Pyrheliograph 5-3850 with a range of 0 to 3 gram-calories per square centimeter per minute. This instrument was located in the vicinity of the 30-meter downwind station during each aerosol run. An average solar radiation value was determined for each 30-minute aerosol sampling period and recorded.

A Bendix Model 566-2 portable, electrically aspirated psychrometer was used to observe wet and dry bulb temperatures downwind of the aeration basin. These readings were recorded after 15 minutes of aerosol run time in the vicinity of the 30-meter sampling station. The reported measurements were the dry bulb temperature and the percent relative humidity (as determined by comparison of the wet and dry bulb temperatures).

During each run visual observations were made of cloud cover, cloud type, and minimum cloud height based on the cloud type. Cloud cover was recorded as the number of eighths of the whole sky covered by any type of cloud formation. Cloud types and cloud heights were determined by visual observation and comparison with photographs found in the Manual of Cloud Forms and Codes for States of the Sky.[3]

Wastewater Samples

Wastewater Characterization of Potential Aerosol Sources--

To adequately design the aerosol monitoring program, knowledge of the wastewater levels of microbial pathogens and viruses was required at the potential sources of aerosol formation: the aeration basins, the surge basins, and the secondary recarbonation basin.

To accomplish this task, sample collection for large-volume 24-hour composites commenced at 0700 on November 8, 1977 at three in-plant locations: the middle of aeration basin A (plant side 2), the middle of the secondary recarbonation basin (plant side 2), and the No. 1 surge basin. The composite samples were collected on a time-weighted basis at each sample location since flow through each of the areas remained relatively constant during the 24-hour period. Automatic ISCO samplers were used for sample collection at the aeration basin and the secondary recarbonation basin. At these sampling points, an 800 mL sample was collected automatically every hour over a 24-hour period. Sample containers were stored in an ice bath resulting in rapid cooling of the wastewater sample to 4°C. At the surge basin, one-liter grab samples were collected manually at bihourly intervals and immediately placed on ice.

At the end of the 24-hour period, the grab (individual) samples for each site were pooled and mixed thoroughly. Each composite sample was divided into 12 labeled one-liter sterile bottles for packing into insulated mailers with wet ice and frozen Kool Pacs.® Shipment to the CART laboratories in San

Antonio was made via counter-to-counter airline parcel service with samples arriving in San Antonio nine hours after preparation of the composite.

Wastewater Samples During Aerosol Monitoring--

During the aerosol monitoring effort, wastewater samples were collected from the two aerosol sources (the single aeration basin in use and the No. 1 surge basin) during the 30-minute aerosol sampling period. This was necessary to determine the source strength concentrations of those microorganisms being assayed in the aerosol samples.

Since the microorganism characteristics of the wastewater in the aeration basin might change quickly due to the short detention time, a time-weighted composite sample was collected. At 5, 15, and 25 minutes into an aerosol run, a two-liter sample was collected from the center of the aeration basin and placed on ice.

Likewise, a grab sample was collected at the No. 1 surge basin. However, since there was no flow into or out of the surge basin during any of the aerosol runs, a six-liter grab was taken at one convenient time within the 30-minute sampling period.

If the criteria for a successful run were all met, the time-weighted composite samples from the aeration basin were composited and transferred to 3 one-liter sterile labeled polypropylene bottles. A small aliquot was transferred to a small glass vial and acidified to pH <2 with concentrated H_2SO_4 for TOC determination. The surge basin grab was placed in 5 one-liter sterile labeled polypropylene bottles. A sample aliquot of the surge basin grab was also preserved for TOC analysis. These samples were stored in an ice bath at 4°C until subsequent shipment on the following day.

High-Volume Aerosol Samplers

One type of high-volume air sampler, the Litton Model M large-volume air sampler, was used for collecting biological aerosols in this monitoring program. These were manufactured by Applied Science Division, Litton Systems, Inc., Minneapolis, Minnesota. For purposes of this study, 12 Model M samplers were loaned to SwRI by the Naval Biosciences Laboratory, Oakland, California.

The sampler is designed to collect airborne particles and concentrate them into a thin, moving film of liquid media. The collection and transfer media selected was brain-heart infusion (BHI) broth with 0.1 percent Tween 80®, which was shown to be adequate for sample concentration and for preservation and assay of the microorganisms.[4] The nominal air flow rate for the samplers is 1,000 liters per minute (lpm) (=1.0 cubic meters per minute), and during the typical aerosol run of 30 minutes, a total air volume of 30,000 liters (=30 m^3) is sampled. A complete description of the sampler is provided in Appendix C.

Field operation of the samplers first required that an effective decontamination be performed followed by suitable storage in this sterile state. This was accomplished by a cleanup procedure using both absolute ethanol and a buffered Clorox® solution, followed by sealing all sampler openings. Samplers were normally decontaminated in the laboratory at the conclusion of an aerosol run. The USA District Laboratory provided a lab area suitable for this purpose. When more than one run was conducted on the same day, decontamination was performed in the field between runs. A copy of the step-by-step cleanup procedure can be found in Appendix B.

The first step in using the Model M for aerosol collection was to level a portable field table with adjustable legs at the desired sampling point. The Model M sampler was then placed in the center of the level table and a portable, gasoline powered alternator was located approximately 10 meters downwind of the sampling site. With this arrangement the air inlet was 1.5 meters (5 feet) above ground level.

The Model M samplers were deployed in the sampling array and operated simultaneously for 30 minutes to constitute an aerosol run. Sampling was always conducted at an air flow rate of 1.0 m^3/min and an electrostatic potential of 14 kilovolts. A more detailed description of the procedures for sampler setup and operation can be found in Appendix A.

ANALYTICAL METHODS

Microbial Wastewater Screen

The large volume microbial screen of the wastewater included analysis for the same indicator organisms as the routine samples. Procedures for these organisms were those described below. In addition, other organisms were sought. The specific methods for these organisms follow:

Salmonellae--

Enrichment for Salmonellae (including Arizona) was carried out following concentration of samples by filtration of measured volumes of the sample (the volume filtrable depending on the level of organic and particulate matter) on diatomaceous earth as described in Standard Methods.[5] Portions of the diatomaceous earth plug and an unconcentrated 10-mL sample were enriched in separate bottles of selenite and tetrathionate broths. After enrichment, aliquots were streaked for isolated colonies onto a moderately selective medium (XLD or Hektoen enteric agar) and highly selective medium (SS). Identificataion of suspect colonies were accomplished by a biochemical screen (oxidase, triple sugar iron, motility-indole-ornithine, lysine, urea). Additional biochemical tests were performed on all colonies with a tentative identification of *Salmonella*.

Shigellae--

A qualitative procedure for the concentration and isolation of Shigella was carried out as described in Standard Methods.[5] Filtration through diatomaceous earth was used to concentrate a large proportion of all microorganisms present in a one- to two-liter sample. The resulting plug of diatomaceous earth was divided into equal portions for addition to bottles of GN broth (BBL). One-half of the same plug was used for enrichment of Salmonella as described above. A 10-mL portion of the unconcentrated sample was added to a separate bottle of enrichment medium. After 24 hours enrichment at 37°C, aliquots from the bottles were plated for isolated colonies onto xylose lysine desoxycholate (XLD) agar. Although several enrichment-plating media combinations are available for isolation of Shigella, the GN-XLD combination repeatedly has been observed to be superior for recovery of the organism.

Proteus--

Proteus was determined by directly plating serial dilutions of the sample onto moderately selective and highly selective enteric media. All colonies were oxidase tested; on those which were negative, a preliminary biochemical screen was performed. All colonies tentatively identified as Proteus were subjected to further biochemical tests for confirmed identification.

Staphylococcus aureus--

During a previous study,[4] a quantitative membrane filter (MF) procedure described in Standard Methods[5] was employed. The sample size was varied in order to yield MF counts within a desired 40-100 colony range on M-Staphylococcus broth-soaked absorbent pads. However, enumeration of yellow pigmented colonies and their subsequent confirmation as S. aureus was complicated by the heavy mixed growth on the filters. This procedure was abandoned and samples (0.1 mL) were spread plated in triplicate directly to previously solidified plates of mannitol salt agar. This change resulted in a marked reduction of "background" growth and was used in this study despite the fact that there was a reduction in the volume of sample that could be analyzed. Typical colonies showing a yellow zone of mannitol fermentation were fished for confirmation of identity by staining techniques and coagulase production.

Mycobacteria--

Mycobacteria were assayed quantitatively by a procedure which almost totally supresses sewage saprophytes while permitting recovery of most mycobacteria. The sample was treated for 20 minutes with 500 ppm of benzalkonium chloride (Zephiran®), diluted and plated to the surface of previously prepared plates of Middlebrook 7H10 agar. Plates were incubated in a 5-percent CO_2 atmosphere and examined over a period of one month for the appearance of typical colonies of mycobacteria. Colonies that appeared were identified by examination of stained (Ziehl-Neelsen) smears for acid-fast bacilli and by other procedures as outlined in Figure 6.

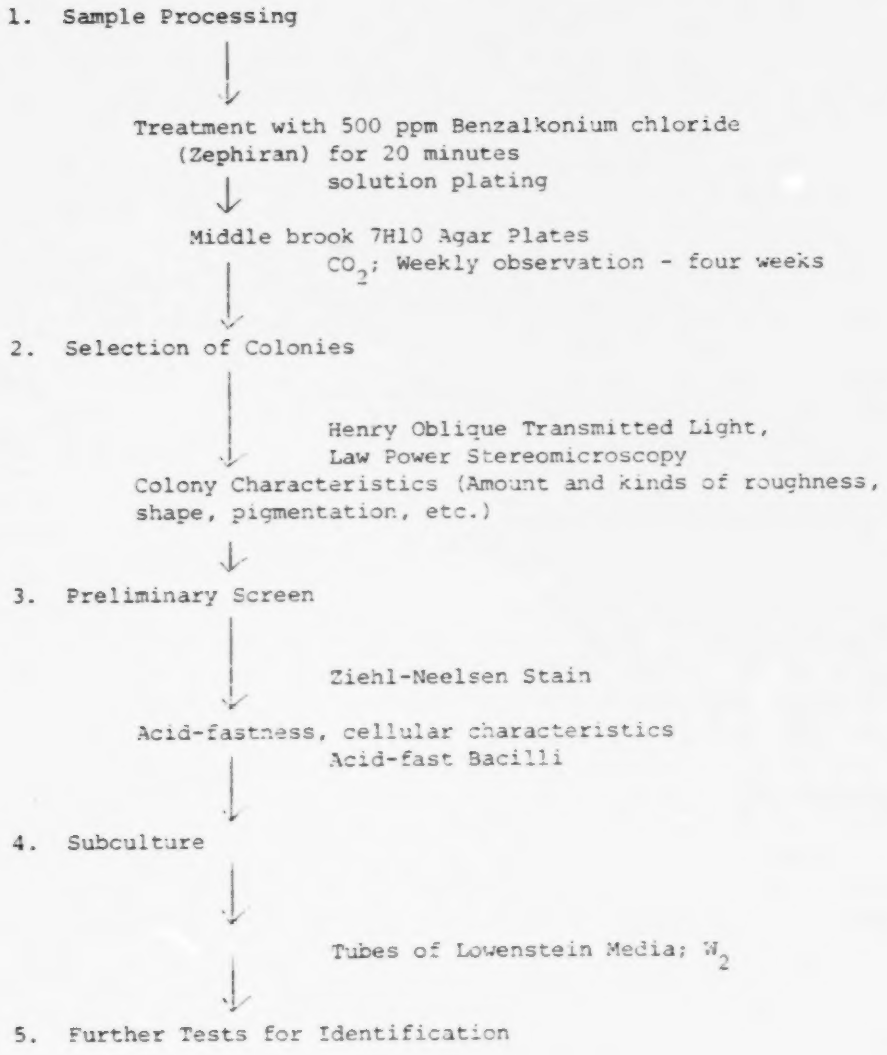

1. Sample Processing
Treatment with 500 ppm Benzalkonium chloride (Zephiran) for 20 minutes
solution plating
Middle brook 7H10 Agar Plates
CO_2; Weekly observation - four weeks
2. Selection of Colonies
Henry Oblique Transmitted Light, Law Power Stereomicroscopy
Colony Characteristics (Amount and kinds of roughness, shape, pigmentation, etc.)
3. Preliminary Screen
Ziehl-Neelsen Stain
Acid-fastness, cellular characteristics
Acid-fast Bacilli
4. Subculture
Tubes of Lowenstein Media; W_2
5. Further Tests for Identification

Figure 6. Schematic Diagram of Mycobacteria Isolation

Klebsiella--

Quantitation of *Klebsiella* in the highly mixed samples is complicated by the lack of an isolation procedure that is highly differential or selective for these organisms. The capacity of *Klebsiella* and *Enterobacter* to fix nitrogen and thus to form large colonies on a nitrogen-deficient medium has been employed for the differential isolation of these organisms from feces. However, the more commonly employed ability of *Klebsiella* to produce large mucoid colonies of differential enteric media containing a high concentration of carbohydrate (e.g., EMB agar) was utilized in this study.

The isolation and identification scheme employed for *Klebsiella* is covered in Figure 7. *Klebsiella* ozaenae and the rare *K. rhinoschleromatis* were screened for in addition to the more common *K. pneumoniae*.

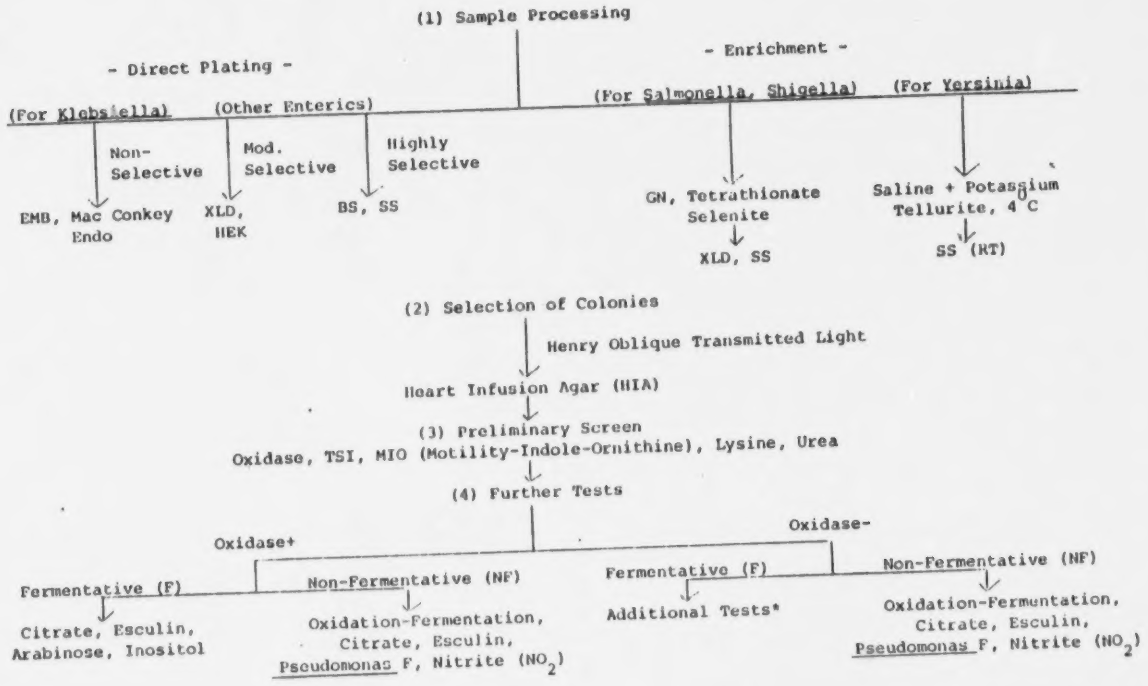
Most *Klebsiella* in nature are encapsulated and give rise to mucoid colonies, but rough forms also occur. Finally, the closely related genera *Enterobacter* and *Serratia*, that "classically" produce less mucoid colonies than *Klebsiella*, cannot be differentiated from the latter on the basis of colonial morphology alone.

The above considerations and the large number of mucoid colonies previously observed following plating of similar samples to the nonselective enteric media, made it apparent that quantitation of *Klebsiella* had to be carried out in an indirect manner. Individual mucoid colonies, randomly picked from wastewater samples were plated to EMB and tested for identification as *Klebsiella*.

Other *Enterobacteriaceae*--

Members of the other genera of *Enterobacteriaceae* (i.e., *Enterobacter*, *Serratia*, *Edwardsiella*, *Escherichia*, *Citrobacter*, *Providencia* and *Yersinia*) were determined by picking colonies from samples dilution plated to moderately selective (XLD and Hektoen) and highly selective (bismuth sulfite and SS) enteric plating media. Since the coliforms (particularly *E. coli*) constitute the major portion of *Enterobacteriaceae* on the nonselective media, their light-to-heavy suppression on the selective media was desirable to increase the chance of picking other types.

Two to three representatives of every colony type observed under low power microscopy with oblique transmitted lighting were subcultured for identification as illustrated in Figure 7. All colony types picked for identification following enrichment for *Salmonella* and *Shigella* as described above were characterized to the species level for inclusion in this aspect of the study also. Colonies from the nonselective enteric plating media (EMB) were not selected for this aspect of the study.


(1) Sample Processing
- Direct Plating -
- Enrichment -
(For Klebsiella)
(Other Enterics)
(For Salmonella, Shigella)
(For Yersinia)
Non-Selective
Mod. Selective
Highly Selective
EMB, Mac Conkey Endo
XLD, HEK
BS, SS
GN, Tetrathionate Selenite
XLD, SS
Saline + Potassium Tellurite, 4°C
SS (RT)
(2) Selection of Colonies
Henry Oblique Transmitted Light
Heart Infusion Agar (HIA)
(3) Preliminary Screen
Oxidase, TSI, MIO (Motility-Indole-Ornithine), Lysine, Urea
(4) Further Tests
Oxidase+
Oxidase-
Fermentative (F)
Non-Fermentative (NF)
Fermentative (F)
Non-Fermentative (NF)
Citrate, Esculin, Arabinose, Inositol
Oxidation-Fermentation, Citrate, Esculin, Pseudomonas F, Nitrite (NO2)
Additional Tests*
Oxidation-Fermentation, Citrate, Esculin, Pseudomonas F, Nitrite (NO2)

* Arabinose, adonitol, arginine dihydrolase, citrate, esculin, JTR (Jordans tartrate), KCN, malonate, MR, MP, mannitol, dulcitol, rhamnose, salacin, sorbitol, motility (wet-mount and/or semisolid agar), indole from tryptone broth, Enterotube®, Salmonella antisera, Shigella antisera.

Figure 7. Schematic Diagram of Enterics Isolation.

Yersinia enterocolitica was determined by selective enrichment of membrane filter-concentrated samples or diluted samples refrigerated in isotonic saline with 25 μg/mL of potassium tellurite and plated to SS agar. After incubation for two days at 25°C, colonies were identified as described previously.

Microbiological Assay

Wastewater--

Total Coliform--Appropriate volumes of sample were filtered through sterile membrane filters and placed on m-Endo LES agar to attain colony counts of 20-80 colony-forming units (cfu) per plate. Incubation was at 35°C ± 0.5°C for 24 hours. Results were reported as total coliform per 100 mL. This procedure was in accordance with the 14th Edition, *Standard Methods*.[6]

Fecal Coliform--Appropriate volumes of sample were filtered through sterile membrane filters and placed on m-FC agar to attain 20-80 colonies per plate. Incubation was at 44.5°C ± 0.5°C for 24 hours. Results were reported as cfu/100 mL. This procedure was in accordance with the 14th Edition, *Standard Methods*.[6]

Fecal Streptococci--Appropriate volumes of sample were filtered through sterile membrane filters to observe a direct count of fecal streptococci. M-Enterococcus agar (Difco) was used as the plating media of choice. Incubation was at 35°C ± 0.5°C for 48 hours. Results were reported as cfu/100 mL.

Total Plate Count--Serial dilutions of the sample (10^{-1} to 10^{-7}) were prepared and spread plated in triplicate. Ten plates of 0.1 mL of sample were plated directly to obtain a total volume of 1.0 mL of sample.

Incubation was at a temperature of 35°C ± 0.5°C for 24 hours ± 2 hours. If bacteria did not develop sufficiently to be detected in 24 hours, incubation was continued through 48 hours.

Only plates showing 30-300 colonies were considered in determining the total plate count. The result reported was the average of all plates falling within these limits.

If colonies per plate in the highest dilution exceeded 300, the result was recorded as greater than 300 times the appropriate dilution factor. Likewise, if no chosen dilution had colonies, the result was recorded as less than one colony per lowest dilution (<cfu/mL). Counts were reported as cfu/mL.

Pseudomonas--Fluorescent pseudomonads (i.e., *Pseudomonas aeruginosa*, *P. putida*, and *P. fluorescens*) were determined by the following procedure. A direct and quantitative approach was found to be more useful than the most probable number analysis for their enumeration, since fluorescent pseudomonads are generally present in large numbers in the large-volume composite samples. Samples were diluted and plated in triplicate onto previously solidified plates of King's medium B, commercially available as Pseudomonas Agar F (Difco), and onto plates of Centrimide Agar (Difco). The former medium is optimal for production of fluorescent pigments (fluorescein) by pseudomonads and the latter is a selective medium for Pseudomonas. Following incubation at 37°C for 48 hours, the number of fluorescent pseudomonads were determined by noting the number of green fluorescing colonies observed with long-wave ultraviolet light in the dark. When the Pseudomonas Agar F were excessively crowded with other types of organisms, all colonies from appropriate dilutions were picked from the selective pseudomonad medium (Centrimide Agar) to sectors of Pseudomonas Agar F plates. Following incubation, the number of fluorescent colonies were determined as described above. In either case, positive colonies were confirmed by demonstrating that they were oxidase positive.

Because of variations in the distribution of other microorganisms in the wastewater, the correspondence of Pseudomonas concentrations obtained on Pseudomonas Agar F and on Centrimide Agar varied from roughly one-to-one in some samples to roughly a twenty-fold reduction on Centrimide Agar in other samples, in no predictable pattern. Thus, the results from both plating methods were reported.

Viruses--Mixed liquor samples from the aeration basin were separated so the solid and liquid fractions could be assayed independently for both coliphage and enteroviruses. The samples were separated by low-speed centrifugation (5,000xg) for five minutes. The liquid fraction was decanted and concentrated (see below) or used for direct plating. The pellet was resuspended in tryptose phosphate broth and homogenized in a tissue grinder prior to further centrifugation and assay.

Concentration

To two liters of sample, 200 mg of expanded bentonite clay and 20 mL of 1.0M $CaCl_2$ was added. The pH was adjusted to 6.0 and the sample mixed magnetically for 30 minutes. The suspended solids were collected by light centrifugation. The supernatant was discarded, the pelleted solids resuspended in tryptose phosphate broth, eluted for five minutes and recentrifuged. The supernatant (approximately 20 mL) was collected for assay. The following test volumes were concentrated routinely: aeration basin, two liters; surge basin, four liters; and recarbonation basin, four liters.

As a control, a known titer of Poliovirus Type I (Chat) was added to 0.5 liter of the liquid fraction of each sample and concentrated. This procedure served to determine the concentration efficiency for each sample as well as a relative cell line plating sensitivity.

Viral Assay

Indigenous viruses were enumerated on either HeLa or HeLa and Buffalo Green Monkey (BGM) monolayers. Values were reported as plaque-forming units (pfu) per liter of original sample (solid or liquid fraction as appropriate). Seeded poliovirus I (Chat) used in concentration controls were assayed on HeLa cell monolayers.

During the November 1977 sampling only HeLa cells were used. In an effort to increase the range of potential viral isolates, BGM cells were added as a second plaque assay system during the aerosol sampling period of March 1978. An apparent advantage of the BGM line was that the cells could be held as viable monolayers for seven days, whereas HeLa monolayers sometimes began deteriorating when incubated as long as seven days. Additionally, the BGM cell line had been reported to be more sensitive than rhesus kidney cells for the isolation of viruses from sewage as evidenced by plaque formation.

The generalized procedure for plaque assay consisted of inoculating confluent cell monolayers grown in 100 mm plates with 1.0 mL of sample. After a 60-minute infection period, monolayers were overlaid with an agar-based Eagle's minimal essential media containing 8 percent calf serum, 200 units of penicillin G per mL, 16.6 units of streptomycin per mL, 25 μg of Gentamicin® per mL, and 0.5 μg of Fungizone® per mL. Infected plates were held at 37°C in a five percent CO_2 humidified incubator. Two days post-infection, a second overlay containing 30 μg per mL of neutral red was placed on each plate.

Plaques were scored at appropriate times. HeLa cell monolayers were observed at three days and five days post-infection. BGM cell monolayers were scored for plaques seven days after infection.

Coliphage--Coliphage samples were assayed using *Escherichia coli* K-13 as the host organism. Samples were prepared as described above. Results were reported as pfu/liter original sample (solid or liquid fraction).

Appropriate volumes (0.1, 0.5, or 1.0 mL) of the wastewater and 0.5 mL of host cells were added to 3.5 mL of liquefied tryptose phosphate semisolid agar (1.0 percent) and poured while warm (43°C) on 100 mm plastic petri dishes prepared with 15 mL of solidified tryptose phosphate agar (1.5 percent) base layer. When firm, the plates were inverted and incubated at 37°C for approximately eight to twelve hours prior to counting. For each sample fraction, a minimum of five plates were used.

Aerosol Samples--

Bacteria--The methods employed in the bacterial analysis of aerosol samples were identical to those employed in the analysis of the wastewater samples.

Coliphage--The total available volume of BHI + 0.1 percent Tween 80® (25 mL) was plated in a manner similar to that described above. The only procedural change was that the 25-mL sample was distributed over twenty to twenty-five 100 mm plates.

Enterovirus Aerosol Study

The enterovirus aerosol study employed procedures developed in conjunction with the Pleasanton research.[4] These methods involve two stages, field concentration and assay, each of which is described below.

Field Concentration--

The classical two-phase polymer separation concentration procedure was used. Appropriate volumes of BHI with 0.1 percent Tween 80® were mixed with sodium dextran sulfate, polyethylene glycol (PEG 6000) and sodium chloride to final concentrations of 0.2 percent, 6.45 percent, and 0.5M, respectively.

The total volume was shaken vigorously in a separatory funnel and held at 4°C for 18 hours to permit adequate phase separation. The lower phase and interphase volumes were collected and diluted (1:3) with Hank's balanced salt solution (HBSS) with appropriate antibiotics. The samples were shipped at 4°C for assay.

Final Assay--

The total volumes of the lower phase and interphase were assayed on HeLa and BGM monolayers as described above. After a 60-minute attachment period, the inoculum was removed by aspiration and the infected monolayers rinsed twice with HBSS with 2X antibiotics prior to overlaying with agar. A second overlay was placed on the plates two days post-infection.

Any areas of cytopathic effect (CPE) having characteristics of viral infection at three days, five days, and seven days post-infection and not directly attributable to microbial contamination were isolated into sterile culture tubes using capillary pipettes. Media 199 containing antibiotics (penicillin, streptomycin, Gentamicin,® and Fungizone®) was added to each tube at 0.5 mL tube. These isolates were held at 4°C for at least 24 hours before infection of tube cultures.

Confluent monolayers of homologous cells grown in stationary tube cultures were infected with 0.2 mL of potential viral isolates. Subsequently, infected cultures were incubated at 37°C in a five percent CO_2-in-air atmosphere.

Tubes were observed for CPE under 40X magnification on a daily basis over a period of five-seven days. Any tubes showing viral-type cytopathology were harvested by freezing-thawing. This procedure constituted first passage of isolates. Tubes which showed no CPE were harvested as described and passaged as "blind" isolates. Uninfected controls were harvested and served as second passage controls also.

Potential viral isolates were subjected to a second passage by inoculating confluent monolayers of appropriate cells with first passage supernatants (0.2 mL/tube). Infected cultures were returned to a 37°C CO_2 incubator. Cultures were observed on a daily basis for CPE. Only those isolates showing viral CPE in first and or second passage were reported as viruses.

Chemical and Physical Analyses of Wastewater

Total Organic Carbon--

Total organic carbon (TOC) analyses were conducted according to Part 505, Organic Carbon (Total), Combustion-Infrared Method found in the 14th Edition, Standard Methods for the Examination of Water and Wastewater.[6] Samples were collected in a glass vial and acidified to pH <2 with concentrated sulfuric acid prior to shipment from the study site. In the laboratory, the samples were homogenized in a tissue grinder, purged with nitrogen for two minutes, and injected twice on a Beckman TOC Analyzer. Since the samples of interest were aerated wastewater, the loss of any volatile organics should be minimal during nitrogen purge.

Total Suspended and Total Volatile Suspended Solids--

Total suspended solids and total volatile suspended solids were determined on a 2- to 25-mL sample aliquot by methods found respectively in Part 208D, Total Nonfiltrable Residue Dried at 103°-105°C (Total Suspended Matter) and 208E, Total Volatile and Fixed Residue at 550°C from the 14th Edition, Standard Methods for the Examination of Water and Wastewater.[6]

Measurements at DAWTP--

Wastewater flow, air flow and dissolved oxygen (DO) were measured continuously by plant instrumentation. Aeration basin wastewater flow was not measured directly but was determined from the secondary clarifier flow measurement since no flow changes occur between these two processes. Secondary clarifier flow was measured by a Rockwell propeller-type flow meter, recorded on a strip chart recorder and integrated for 24-hour wastewater flow. Air flow was not measured in a standardized air volume unit, but the values indicate relative amounts of air used over a 24-hour operating day. A Robertshaw floating DO probe was used to measure dissolved oxygen in the aeration basin, and an occupational check was performed with a laboratory model Yellow Springs DO Meter.

AEROSOL SAMPLING PROTOCOLS

Microbiological Aerosol Runs

The objective on the microbiological aerosol runs was to simultaneously measure the microorganism levels and their decay from the two sources of aerosol: the aeration basin and the No. 1 surge basin. This was achieved using a sampler array of eight high-volume air samplers (Litton Model M). As indicated in Table 3, two samplers were paired upwind, while the six downwind samplers were deployed as three pairs, at planned distances of 30 m and 100 m downwind of the aeration basin and 50 m downwind of the surge basin. On most runs the actual distances that the samplers were positioned downwind from the aerosol sources differed from the planned distances, since terrain limitations and the presence of plant structures precluded sampling at the exact planned sampler distances. After each run, the pairs of samples collected at the UPWIND, AB100 and SB50 stations were pooled to enhance sensitivity. The two samples from the AB30 station were processed separately, with the designation AB30L (left sampler) and AB30R (right sampler). The actual deployment of samplers and meteorological towers for Run 1 is depicted in Figure 8.

TABLE 3. SAMPLER ARRAY FOR MICROBIOLOGICAL AEROSOL RUNS

Station Designation	Aerosol Source Sampled	Planned Location	No. of Samplers	Sample Processing
Upwind	Background	Upwind of DAWTP Sources	2	Pooled
AB30	Aeration Basin (AB)	≈30 m downwind of AB	2	Separate (AB30L, AB30R)
AB100	Aeration Basin (AB)	≈100 m downwind of AB	2	Pooled
SB50	No. 1 Surge Basin (SB)	≈50 m downwind of SB	2	Pooled

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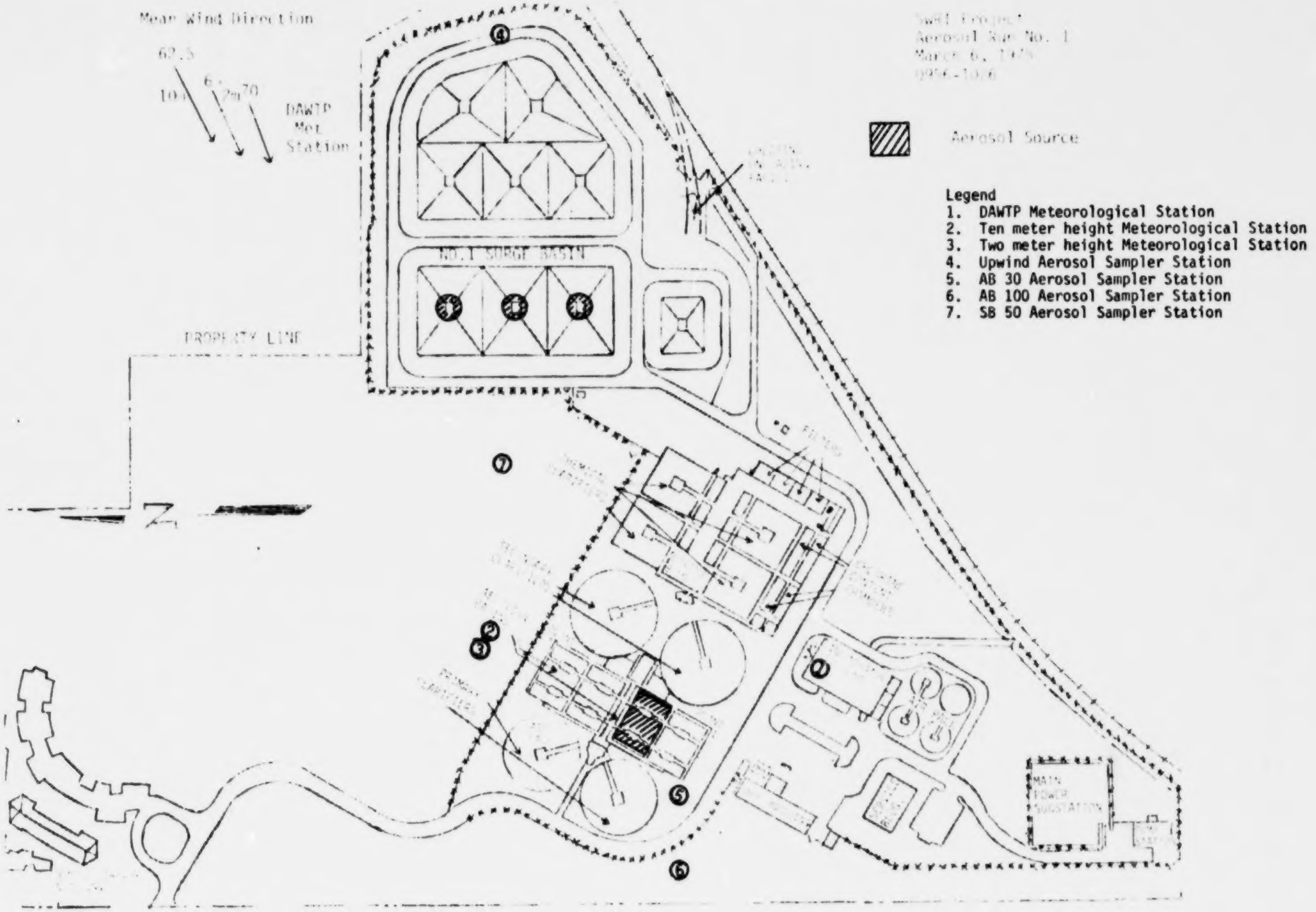

▨ Aerosol Source

Legend
1. DAWTP Meteorological Station
2. Ten meter height Meteorological Station
3. Two meter height Meteorological Station
4. Upwind Aerosol Sampler Station
5. AB 30 Aerosol Sampler Station
6. AB 100 Aerosol Sampler Station
7. SB 50 Aerosol Sampler Station

Figure 8. Aerosol Run No. 1.

Initially, the spacing of the pair of samplers at each sampling site was 1 m apart. However, after the third aerosol run, the sampler separation at each downwind sampling site was increased in an attempt to maintain either one or both of the samplers in the aerosol cloud when shifts in wind direction occurred. Thereafter, the AB30 samplers were spaced 2 m apart, and the AB100 and SB50 samplers were spaced 8 to 10 m apart. The upwind sampler spacing remained 1 m.

An aerosol run was attempted only when proper meteorological conditions prevailed.

General weather conditions were determined by contacting the National Weather Service at Portland International Airport each day and by monitoring weather forecasts broadcast on the local news media. During periods of attempted aerosol sampling, micrometeorological conditions in the vicinity of the plant were monitored by continuously observing wind speed and wind direction at both the SwRI meteorological station and the DAWTP instrumentation.

When wind speed and wind direction remained relatively constant for a minimum of 15 minutes and the terrain in the downwind direction permitted sampling, locations for the sampling stations were selected and they were set up as described in Section 5, under "High-Volume Aerosol Samplers". The downwind stations were located so that they were in the center of the plume emanating from the aerosol source. Forecasts of rain were closely monitored. No aerosol runs were attempted during periods of rainfall because Model M samplers cannot be operated during periods of precipitation and high humidity due to high voltage arcing problems.

After samplers were in position and all accessory equipment in place, wind speed and wind direction were evaluated prior to commencing a run. If the wind was still suitable for sampling the aerosol plume from the selected sampler positions, the run was initiated. The procedure for actual collection of the samples during the 30-minute run is given briefly in Section 5, under "High-Volume Aerosol Samplers" and in detail in Appendix A.

At the end of the run, wind direction data from the 2 m and 10 m heights at the SwRI meteorological station and from the DAWTP station were evaluated. To evaluate the data, the following criteria were established as guidelines for a good aerosol run:

(1) Average wind direction for the two 15-minute segments of the run was no more than 30° from the wind direction used for sampler setup.

(2) The extremes of wind direction (excluding outlier spikes) was no more than 70° from the wind direction average.

(3) Six of the eight aerosol samplers successfully completed the run.

(4) No precipitation occurred during the run.

If these criteria were satisfied, samples were pooled where required, labeled and stored at 4°C until shipment on the next day. On the following day, samples were packed in an insulated mailer with a frozen Kool Pac® and shipped via the counter-to-counter parcel service of a scheduled commercial airline. With this arrangement, the maximum time between sample collection and arrival in the CART laboratory was 28 hours, although typically less than 24 hours elapsed.

Enterovirus Aerosol Run

The objective of the virus study was to determine the enterovirus aerosol concentration just downwind of the DAWTP aeration basin using specialized sampling methodologies and concentration methods. First it was necessary to determine if measurement of enteric virus in aerosols downwind of aeration basins in an activated sludge wastewater treatment plant was practical with state-of-the-art sampling procedures and equipment. Due to relatively low concentrations of viruses in wastewaters, it is difficult to detect aerosolized viruses even with the level of sensitivity available with the high-volume samplers. From the results obtained for spray aerosols in a previous study, it appeared that at least 1500 m^3 of air must be sampled to warrant conducting an enterovirus aerosol run.

To meet this requirement, the eight high-volume samplers were operated simultaneously for nine consecutive 30-minute sampling periods in close proximity to each other (~2 m apart) at 30 m downwind of the aeration basin. After each 30-minute sampling period, the sample containers with 100 mL of BHI media were capped and cooled to 4°C, and a new sampling period initiated for an additional 30 minutes. At the end of the virus run, all BHI collected was transported to the USA District Laboratory for concentration. The procedure used for field concentration of BHI is given in Appendix D.

During the virus run, a one-liter aeration basin grab sample was collected every 15 minutes concurrently with areosol sampling and cooled to 4°C immediately after collection. The grab samples were composited in the laboratory and transferred to 3 one-liter containers for shipment to the CART laboratories.

Some variation in wind direction could be tolerated during a 30-minute run period since the samplers were only 30 m from the broad aerosol source provided by the aeration basin. Some shifting in wind direction over the duration of the enterovirus aerosol run was also tolerable, since samplers could be moved between the 30-minute run periods.

SCHOOL ATTENDANCE ACCOUNTING SYSTEM

Attendance is the daily count of the number of pupils present at a particular school for any given segment of the day when school is in session. Pupil attendance is measured as total days present, total days absent, and total days membership. The sum of total days present and total days absent is equal to total days membership. The accounting of pupil attendance is generally very accurate, because attendance data is the basis for the apportionment of state funds for school operation.

For the schools in the Tigard School District and Lake Oswego School District, attendance is recorded daily by the teachers on preprinted documents called "Attendance Data Collection and Recording Form" (see Appendix E for sample copy). It should be noted that absences are carried on a half-day and full-day basis. The criteria for determining a half-day's or full-day's absence is based on the number of class hours missed. If a pupil misses two class hours, the pupil is marked absent for half a day. If the pupil misses more than four and one-half class hours, the pupil is marked absent for a full day.

Teachers record the names of absent students each day. At the end of the week, all attendance data collection and recording forms are forwarded to the school secretary who enters the information into an automated data system. From the attendance data base, the "Pupil Personnel Attendance Accounting" (PPAA) quarterly report is prepared.

The PPAA is a computer-generated summary of a particular school's enrollment that is prepared for each quarter year and the entire school year to fulfill Oregon's state-wide attendance reporting requirements (see Appendix E for the PPAA form and explanation of attendance codes). Cumulative enrollment statistics are provided for three distinct grade group distributions (kindergarten, grades one through eight, and grades nine through twelve) at each school. For each of the three groups, attendance is reported in terms of total days present, total days absent, and total days membership for the reporting period. Thus, the pertinent attendance data that can readily be obtained for each school being studied are total days of presence, absence, and membership of all students in [illegible] through six for each quarter year.

Neither the state nor the respective school district administrative offices maintain attendance records on a grade-by-grade basis for a given school. It is necessary to go to the records kept at the school to obtain total days present, total days absent, and total days membership for each grade level. Thus, attendance data by grade at a given school is generally more difficult to obtain. This data was obtained only for Durham Elementary and two control schools to conduct a confirmatory cohort analysis.

DATA FLOW, PROCESSING, AND ANALYSIS METHODS

Wastewater Aerosol Monitoring Data

An integrated data system involving a unique sample code, computer-generated sample labels, and field data reporting forms was used for this study. The sample code identified the relevant aspects of a sample portion: its run number, sample location, medium (wastewater or aerosol), sample analysis, sample volume, and the project number. This identity was transmitted with the analytical values from sample collection through processing, shipping, preparation, analysis, reporting, and statistical analysis.

Computer-generated sample labels were used to affix the sample code to every bottle containing the sample or a portion of the sample. Typical sample labels are given in Figure 9. For example, the label in the lower left-hand corner of Figure 9 with sample code 5-SURGE-TOC-5082 would be placed on the bottle containing the portion of wastewater from the surge basin on Run 5 of this study (5082). It is to be analyzed for total organic carbon.

An efficient data reporting system was also developed. Data forms for reporting field and laboratory results were coded in a suitable data entry format. Coded examples of the following environmental monitoring data forms are presented in Appendix E.

- Aerosol Run Report on Meteorology
- UTSA-CART Wastewater Analysis Report
- UTSA-CART Aerosol Run Analysis Report

As these coded examples illustrate, each laboratory result was identified by including the relevant parts of the sample code on the laboratory data form. Upon completion of a sampling period, an entire set of data forms were forwarded by the laboratory or field supervisor for data processing and analysis.

School Attendance Data

School attendance data for each of the nine study schools were obtained by grade (one through six), school, year, and quarter year from 1969-70 through 1977-78. For the schools in the Lake Oswego School District, only annual totals were available for 1969-70 through 1974-75.

Additional attendance data were collected for Durham and two control schools in the Tigard School District (Tualatin and Templeton Elementary Schools) by school, individual grade levels, year, and quarter year from 1971-72 through 1977-78.

RUN NO. 5
5-AER.B-1 L-5082
WASTEWATER
AERATION BASIN
1 LITER

RUN NO. 5
5-AER.B-1 L-5082
WASTEWATER
AERATION BASIN
1 LITER

RUN NO. 5
5-AER.B-1 L-5082
WASTEWATER
AERATION BASIN
1 LITER

RUN NO. 5
5-AER.B-TOC-5082
WASTEWATER
AERATION BASIN
TOC

RUN NO. 5
5-SURGE-1 L-5082
WASTEWATER
SURGE BASIN
1 LITER

RUN NO. 5
5-SURGE-1 L-5082
WASTEWATER
SURGE BASIN
1 LITER

RUN NO. 5
5-SURGE-1 L-5082
WASTEWATER
SURGE BASIN
1 LITER

RUN NO. 5
5-SURGE-1 L-5082
WASTEWATER
SURGE BASIN
1 LITER

RUN NO. 5
5-SURGE-1 L-5082
WASTEWATER
SURGE BASIN
1 LITER

RUN NO. 5
5-SURGE-TOC-5082
WASTEWATER
SURGE BASIN
TOC

RUN NO. 5
5-A30L-100-5082
AEROSOL
30M-LEFT
100ML

RUN NO. 5
5-A30R-100-5082
AEROSOL
30M-RIGHT
100ML

RUN NO. 5
5-A100-100-5082
AEROSOL
100M
100ML

RUN NO. 5
5-A100-200-5082
AEROSOL
100M
200ML

RUN NO. 5
5-S50-100-5082
AEROSOL
SURGE-50M
100ML

RUN NO. 5
5-S50-200-5082
AEROSOL
SURGE-50M
200ML

RUN NO. 5
5-UPWIND-100-5082
AEROSOL
UPWIND
100ML

RUN NO. 5
5-UPWIND-200-5082
AEROSOL
UPWIND
200ML

Figure 9. Typical Sample Labels

Examples of the following school attendance monitoring and reporting forms are presented in Appendix E.

- Attendance Data Collection and Recording Form
- Pupil Personnel Attendance Accounting Form 81-581-3200
- Attendance Codes
- Summary of Enrollment Data by School, Year, and Quarter Year
- Summary of Enrollment Data by School, Year, Quarter Year, and Grade Level

The school attendance data constitute time series and were analyzed as such. Because the student body at a school changes primarily through addition of the first grade class and graduation of the sixth grade class each year, values of attendance statistics for a school from one year to the next cannot be considered independent. Hence, classical statistical tests, which assume independent of observations, are not strictly applicable. Simple inspection of the time series did not disclose patterns consistent with adverse DAWTP health effects. With this negative result apparent upon inspection, a formal Box-Jenkins type of time series analysis was not considered to be warranted.

SECTION 6

RESULTS

MONITORING OF WASTEWATER AEROSOLS

Microbial Characterization of Wastewater

Results of microbiological screens of three large volume wastewater samples which were collected from the aeration basin, the surge basin, and the secondary recarbonation basin are presented in Tables 4 and 5. Except for mycobacteria, the bacterial levels shown in Table 4 are minimal values, since only a portion of the total number of colonies counted on a given media were subjected to confirmation biochemical testing. The actual microorganism concentration might have been anywhere from the indicated value to an order of magnitude higher. The concentration levels for mycobacteria and *Klebsiella* were fairly high relative to the microbiological indicators. However, *Salmonella* and *Shigella*, generally regarded the most common bacterial pathogens, were not prevalent in these wastewater samples.

The wastewater concentrations of the microorganism groups being considered for routine monitoring at the Durham site are presented in Table 6 for the same three large volume samples. Included in the data are groups usually considered to be indicator organisms (total plate count, total coliform, fecal coliform, and coliphage), and specific pathogens. Table 6 also provides a comparison of wastewater concentration levels for the three wastewater aerosol sources at the Durham Advanced Wastewater Treatment Plant (DAWTP) relative to two other wastewater aerosol sites which had recently been monitored. Microorganism concentration levels tend to be higher in the aeration basins than in the surge basin, recarbonation basin or effluent pond. This is also true at the DAWTP. Consequently, the aeration basin was selected as the most suitable source for monitoring microorganism aerosols on the aerosol runs at the DAWTP.

Our experience in detecting microorganisms in the aerosol monitoring at the Egan aeration basin and the Pleasanton spray fields guided the selection of microorganisms for routine monitoring in Phase 2. Based on the relative wastewater levels in Table 6, the following microorganism groups were selected for routine monitoring: total coliform, fecal streptococci, *Pseudomonas*, mycobacteria, and coliphage. It should be noted that mycobacteria and *Pseudomonas* were found at relatively high concentration levels.

TABLE 4. BACTERIAL RESULTS FROM MICROBIOLOGICAL SCREENS OF WASTEWATER SAMPLES COLLECTED AT THREE AEROSOL SOURCES, DURHAM ADVANCED WASTEWATER TREATMENT PLANT

Wastewater Source	Aeration Basin	Surge Basin	Secondary Recarbonation Basin
Date	11/9/77	11/9/77	11/9/77
Sample Temperature (upon laboratory receipt)	2°C	1°C	1°C
Sample pH	6.4	7.9	6.6
Bacteria, cfu/100 mL			
Citrobacter diversus	3,300	3,300	330
Citrobacter freundii	3,300	≥10 (E)	670
Enterobacter aerogenes	3,300	≥ 0.30 (E)	330
Enterobacter agglomerans	6,700	13,000	330
Enterobacter cloacae	40,000	3,300	3,000
Esherichia coli	6,700	1,000	1,700
Klebsiella ozaenae	6,700	330	330
Klebsiella pneumoniae	30,000	3,700	1,700
Mycobacteria sp.	1,300,000	970,000	1,100,000
Proteus sp.	<3,300 (ND)	<330 (ND)	<330 (ND)
Proteus mirabilis	--	≥0.30 (E)	≥0.30 (E)
Proteus morganii	--	--	≥0.30 (E)
Providencia sp.	<3,300 (ND)	<330 (ND)	--
Providencia alcalifaciens	--	--	≥10 (E)
Providencia stuartii	≥10 (E)	--	330
Salmonella sp.	<3,300 (ND)	<0.10 (ND)	<0.10 (ND)
Salmonella enteritidis	≥2.5 (E)	--	--
Serratia liquefaciens	3,300	330	3,300
Serratia rubidea	3,300	<330 (ND)	--
Shigella sp.	<0.83 (ND)	<0.10 (ND)	<0.10 (ND)
Staphylococcus sp.	330	<100 (ND)	<100 (ND)
Yersinia	<6.7 (ND)	<2.0 (ND)	<2.0 (ND)

ND - none detected.
E - enrichment technique.

TABLE 5. BACTERIAL ISOLATION RESULTS FROM THE MICROBIOLOGICAL SCREENS, DURHAM ADVANCED WASTEWATER TREATMENT PLANT

Wastewater Source	Aeration Basin	Surge Basin	Secondary Recarbonation Basin
Date	11/9/77	11/9/77	11/9/77
Sample Temperature	2°C	1°C	1°C
Sample pH	6.4	7.9	6.6

Bacteria	Isolates Identified of Total Colonies Picked %	Isolates Identified of Total Colonies Picked %	Isolates Identified of Total Colonies Picked %
Citrobacter diversus	2.9	11	4.5
Citrobacter freundii	6.7	--	5.6
Enterobacter aerogenes	2.9	--	4.5
Enterobacter agglomerans	5.7	44	4.5
Enterobacter cloacae	34	11	41
Esherichia coli	5.7	11	23
Klebsiella ozaenae	5.7	3.7	2.8
Klebsiella pneumoniae	26	34	14
Mycobacteria sp.[a]	100	100	100
Providencia stuartii	--	--	4.5
Serratia liquefaciens	2.9	3.7	13
Serratia rubidea	6.7	--	--
Staphylococcus sp.	4.5	--	--

---

[a] Of the total colonies presumed to be mycobacteria, all isolates were identified as mycobacteria.

TABLE 6. A COMPARISON OF THE MICROORGANISM CONCENTRATIONS IN THE WASTEWATER BEFORE AEROSOLIZATION AT VARIOUS SITES

	Durham Advanced Wastewater Treatment Plant Wastewater Sample Results			Geometric Mean	
	Aeration Basin	Surge Basin	Secondary Recarbonation Basin	John E. Egan Plant Primary Aeration Basin	Pleasanton Sewage Treatment Plant Wastewater Effluent Pond
Total Plate Count (spc/mL)	4,800,000	210,000	12,000	5,900,000	610,000
Total Coliform (cfu/mL)	1,800	1,100	130	400,000	7,100
Fecal Coliform (cfu/mL)	530	160	83	22,000	1,020
Fecal Streptococci (cfu/mL)	67	13	3.4	740	62
Pseudomonas (Agar F/Centrimide)[a] (cfu/mL)	230/56	100/66	CS/6.6	8,600	2,600
Mycobacteria (cfu/mL)	13,000	9,700	11,000	1,000	46
Klebsiella (cfu/mL)	370	40	20	8,000	450
Coliphage (pfu/mL)	61	<0.20	14	120	275
Enteroviruses (pfu/mL)					
3 Day	0.60	0.0018	0.0024	0.13	0.023
All	0.74	0.0092	0.013	0.13	0.033

[a] Pseudomonas results from both methods are reported.

Fecal streptococci, Pseudomonas, mycobacteria and coliphage survive aerosolization well enough that at the measured aeration basin concentrations, they should regularly be found in downwind aerosol samples taken with high-volume samplers. Total coliform and coliphage were the microbiological indicators selected for monitoring to provide continuity with other monitoring studies.

Aerosol Run Data

Meteorology--

The meteorological measurements taken at the DAWTP included air temperature, relative humidity, wind direction, wind speed, and solar radiation intensity. A site map giving the location of the wind measurement stations was presented in Figure 8 in the Methods and Materials section. This map also shows the location of the aerosol sources, the wind direction, and the aerosol sampler locations during Run 1.

The environmental conditions during the six high volume aerosol runs and the nine aerosol sampling runs taken for the virus study are presented in Table 7. The time and date of the aerosol sampling run are also included along with the descriptive environmental measurements.

Air temperature and relative humidity measurements were taken at the AB30 station (approximately 30 meters downwind of the aeration basin). On the first run, the air temperature and relative humidity taken upwind of the aeration basin were the same as the measurements recorded at AB30. Hence, upwind measurements were discontinued after the first run.

The wind direction and wind speed measurements were taken at the two-meter height and at the ten-meter height at the SwRI meteorological station and at the DAWTP meteorological station for the six aerosol runs. For the enterovirus aerosol run, these two wind measurements were taken only at the ten-meter height at the SwRI meteorological station. The mean wind direction in degrees is given relative to true north. The wind direction range shows the variation in wind direction during each run, excluding transitory wind shifts that appeared as outlier spikes on the recording strip charts.

The aerosol runs were taken over a wide range of solar radiation conditions, from darkness during Run 3 to noon during Run 6. The runs were made under partly cloudy to overcast conditions, which are typical for the area during March and favorable for producing the steady winds necessary for aerosol sampling.

Wastewater Levels--

Tables 8 and 9 present the physical, chemical, and microbiological characteristics of the wastewater during the seven aerosol sampling runs.

TABLE 7. AEROSOL RUN METEOROLOGICAL DATA SUMMARY

Aerosol Runs			Air Temperature, °C	Relative Humidity, %	Mean Wind Direction, deg			Wind Direction Range, deg
Run No.	Run Date	Time of Run	at AB30	at AB30	10m. Height	2m. Height	DAWTP Station	10m. Height
1	3-6-78	0956-1026	11	72	65	63	70	45 - 75
2	3-8-78	1544-1614	14	55	325	335	15	285 - 360
3	3-8-78	2305-2335	9.4	78	280	290	320	245 - 315
4	3-9-78	1040-1110	10	65	320	-	15	255 - 355
5	3-11-78	1625-1655	8.5	63	275	-	300	215 - 300
6	3-12-78	1155-1225	10	49	175	-	220	115 - 225
7 Enterovirus Run								
a.	3-12-78	1415-1445	10.0	55	180	-	-	125 - 235
b.	3-12-78	1502-1532	11	48	140	-	-	115 - 195
c.	3-12-78	1540-1610	10	55	170	-	-	135 - 215
d.	3-12-78	1620-1650	10	53	160	-	-	120 - 195
e.	3-12-78	1658-1728	-	-	140	-	-	105 - 175
f.	3-12-78	1735-1805	9.7	63	160	-	-	115 - 180
g.	3-12-78	1815-1845	8.9	63	155	-	-	120 - 180
h.	3-12-78	1855-1925	8.7	64	150	-	-	125 - 175
i.	3-12-78	1933-2003	8.6	63	120	-	-	90 - 145

Aerosol Runs			Mean Wind Speed, m/sec.			Cloud Conditions			Solar Radiation
Run No.	Run Date	Time of Run	10m. Height	2m. Height	DAWTP Station	Cloud Cover in Eighths	Minimum Cloud Height, m	Cloud Type	W/m^2
1	3-6-78	0956-1026	2.5	2.2	1.8	8	3,700-4,300	M7, L5	170
2	3-8-78	1544-1614	1.6	1.6	2.1	8	6,400-7,300	H8, L7	210
3	3-8-79	2305-2335	2.4	1.8	2.2	4	3,400-4,000	M	0
4	3-9-78	1040-1110	2.1	-	2.2	5	2,100-2,700	L4	98
5	3-11-78	1625-1655	5.6	-	5.4	6	1,800-2,400	L4, L7	280
6	3-12-78	1155-1225	2.4	-	2.2	6	1,800-2,400	L4, L5, L7	630
7 Enterovirus Run									
a.	3-12-78	1415-1445	3.8	-	-	6	1,200-1,500	L4, L5, L7	-
b.	3-12-78	1502-1532	3.0	-	-	8	1,200-1,500	L4, L7	-
c.	3-12-78	1540-1610	2.9	-	-	8	1,200-1,500	M1	-
d.	3-12-78	1620-1650	2.9	-	-	8	1,200-1,500	M7	-
e.	3-12-78	1658-1728	2.2	-	-	-	-	-	-
f.	3-12-78	1735-1805	2.5	-	-	-	-	-	-
g.	3-12-78	1815-1845	2.1	-	-	-	-	-	-
h.	3-12-78	1855-1925	1.7	-	-	-	-	-	-
i.	3-12-78	1933-2003	1.5	-	-	-	-	-	-

TABLE 8. PHYSICAL AND CHEMICAL CHARACTERISTICS OF WASTEWATER SAMPLES DURHAM ADVANCED WASTEWATER TREATMENT PLANT

Parameter	Units	Wastewater Source [a]	Wastewater Data						
Aerosol Run No.			1	2	3	4	5	6	7
Date			3-6-78	3-8-78	3-8-78	3-9-78	3-11-78	3-12-78	3-12-78
Time [b]			0956-1026	1544-1614	2305-2335	1040-1110	1625-1655	1155-1225	
PHYSICAL CHARACTERISTICS									
Wastewater Flow	MGD	AB	14.0	14.8	14.8	16.7	12.8	12.9	12.9
Air Flow		AB	1441	1673	1673	1686	1466	1392	1392
Water Temperature	°C	AB	18	18	18	18	18	18	18
Total Suspended Solids	mg/L	AB	1600	1475	1350	1295	2450	2475	2250
		SB	92	96	100	70	136	128	
Total Volatile Suspended Solids	mg/L	AB	750	1000	875	580	1225	1275	1125
		SB	56	48	32	28	62	52	
CHEMICAL CHARACTERISTICS									
Dissolved Oxygen	mg/L	AB	1.1	1.0	1.3	1.9	2.1	2.5	2.5
Total Organic Carbon	mg/L	AB	420	260	340	140 [c]	820	185	650
		SB	52	37	36	34	114	51	

[a] AB-Aeration Basin; SB-Surge Basin

[b] Time range within which a portion of the composite grab sample was taken at three ten minute intervals.

[c] Value maybe low due to loss of some suspended solids during N_2 purge.

TABLE 9. MICROORGANISM CONCENTRATIONS OF WASTEWATER SAMPLES
DURHAM ADVANCED WASTEWATER TREATMENT PLANT

Parameter	Units	Wastewater Source[a]	Wastewater Data						
Aerosol Run No.			1	2	3	4	5	6	7 (Virus Run
Date			3-6-78	3-8-78	3-8-78	3-9-78	3-11-78	3-12-78	3-12-78
Time[b]			0956-1026	1544-1614	2305-2335	1040-1110	1625-1665	1155-1225	
Bacteria									
Total Coliform	cfu/mL	AB	510,000	510,000	490,000	380,000	500,000	420,000	370,000
		SB	77	43	58	43	26	36	
Fecal Streptococci	cfu/mL	AB	4,100	5,400	5,400	3,300	5,600	3,900	4,500
		SB	5.1	4.5	6.1	5.1	5.6	5.3	
Mycobacteria	cfu/mL	AB	24,000	21,000	24,000	25,000	100,000	670,000	120,000
		SB	1,100	25	17,000	350	3,500	20	
Pseudomonas	cfu/mL								
·Agar F		AB	CS	CS	CS	670	20,000	1,700	230
·Centrimide Agar		AB	570	730	430	2,200	730	1,900	1,100
·Agar F		SB	3,700	530	500	1,800	900	2,300	
·Centrimide Agar		SB	3,700	40	23	80	70	270	
Coliphage									
Coliphage (total count)	pfu/mL	AB	380	960	530	990	1,200	260	1,200
·solids fraction	pfu/mL	AB	220	500	340	750	270	210	68
·liquids fraction	pfu/mL	AB	160	460	190	240	900	49	1,100
Coliphage (total count)	pfu/mL	SB	0.6	0.8	0.6	0.2	0.4	<0.2	
Enteroviruses									
Three-day Enteroviruses (HeLa)	pfu/mL								
·Total count		AB	0.78	0.49	0.48	>0.21	0.39	0.38	0.36
·Solids fraction		AB	0.76	0.48	0.46	0.21	0.38	0.37	0.36
·Liquid fraction		AB	0.016	0.0086	0.024	m	0.007	0.0068	0.0047
·Total count		SB	0.029	<0.00005	0.001	0.0024	0.0025	0.003	
Seven-day Enteroviruses (BGM)	pfu/mL								
·Total count		AB	0.28	0.11	0.13	0.12	0.091	0.10	0.044
·Solids fraction		AB	0.26	0.11	0.13	0.12	0.089	0.10	0.044
·Liquid fraction		AB	0.02	0.0013	0.0014	m	0.002	<0.0017	0.0017
·Total count		SB	0.0032	<0.00005	<0.00005	0.0016	0.0025	<0.001	

[a] AB - Aeration Basin; SB - Surge Basin

[b] Time range within which a portion of the composite grab sample was taken at three ten minute intervals.

m Sample lost in laboratory accident

CS Contaminated sample.

Physical and chemical measurements of the aeration and surge basins were made during the seven high volume aerosol sampling runs. Shown in Table 8 are the wastewater flow, air flow, water temperature, total suspended solids, volatile suspended solids, dissolved oxygen, and total organic carbon.

Table 9 shows the microorganism concentration levels in the wastewater for the two wastewater aerosol sources at the DAWTP: the aeration basin and the surge basin. The data in Tables 8 and 9 indicate that the bacteriological quality of the wastewater in the surge basin is substantially better than that in the aeration basin. Whereas most microorganism concentrations remained quite stable during the week of sampling, the mycobacteria levels measured in the wastewater varied considerably, especially in the surge basin. This must be attributed to the biological variability and the nature of the mycobacteria assay (see Methods and Materials section).

Aerosol Levels (Runs 1-6)--

Table 10 presents the wastewater and aerosol concentration levels of the microorganisms selected for routine monitoring on the six aerosol sampling runs. The microorganism aerosol levels are taken upwind and at several distances downwind from the aeration and surge basins. Sampling layouts for each of the aerosol sampling runs showing the aerosol sources, the wind direction, and the locations of the four sampler stations are presented in Appendix F. The planned downwind sampler distances (30 m for AB30, 100 m for AB100, and 50 m for SB50) could often not be implemented because of obstructions such as buildings, plant equipment, and terrain. The actual downwind distances of the sampler stations given in Table 10 and Appendix E can be determined from the Appendix F layouts. These actual downwind distances are given in Table 11. During Run 2, for example, AB30 was 40 m downwind and AB100 was 90 m downwind from the edge of the aeration basin, while SB50 was 70 m downwind from the edge of the nearest aerator's splash in the surge basin.

The microorganism aerosol concentration levels tend to decrease with increasing downwind distance from the wastewater aerosol source. For example, on aerosol Run 1, the aerosol concentration of total coliform increased from less than 0.07 cfu/m^3 (none detected) upwind of the aeration basin, to 4.7 cfu/m^3 (left sampler) and 2.8 cfu/m^3 (right sampler) at 30 meters downwind, and to 0.47 cfu/m^3 at 70 meters downwind. With the exception of mycobacteria, the aerosol concentrations obtained downwind of the surge basin were comparable to the aerosol concentrations obtained upwind of the DAWTP.

The microorganism aerosol concentration levels also tend to vary from one aerosol run to another due to variations of microorganism levels in the wastewater. However, high and extremely variable aerosol concentration levels are probably due to contamination of the high-volume aerosol samplers.

TABLE 10. SELECTIVE MICROORGANISM AEROSOL CONCENTRATIONS UPWIND AND DOWNWIND FROM SOURCE BOUNDARY

	Microorganism Concentrations						
	Background	Aeration Basin				Surge Basin	
			Downwind Aerosol Samples (No./m^3)				
Aerosol Run No.	Upwind Aerosol Sample (No./m^3)	Wastewater Sample (No./mL)	AB30L	AB30R	AB100	Wastewater Sample (No./mL)	Downwind Aerosol Sample (No./m^3) SB50
			Total Coliform (cfu)				
1	<0.07	510,000	4.7	2.8	0.47	77	<0.07
2	<0.07	510,000	NS	2.3	0.20	43	<0.07
3	<0.07	490,000	9.3	9.0	2.5	58	0.40
4	<0.07	380,000	5.0	3.2	0.53	43	<0.07
5	<0.07	500,000	11	3.3	3.7	26	<0.07
6	<0.07	420,000	5.0	6.3	0.53	36	<0.07
			Fecal Streptococci (cfu)				
1	<0.07	4,100	1.3	1.1	0.13	5.1	<0.07
2	0.13	5,400	NS	2.2	0.47	4.5	<0.07
3	<0.07	5,400	3.7	2.1	0.93	6.1	<0.07
4	0.07	3,300	1.6	1.8	0.33	5.1	<0.07
5	<0.07	5,600	1.6	0.76	1.93	5.6	<0.07
6	<0.07	3,900	2.9	2.3	0.73	5.3	<0.07
			Mycobacteria (cfu)				
1	<0.08	24,000	8.0	9.3	0.83	1,100	0.43
2	<0.08	21,000	NS	33	2.8	25	<0.08
3	<0.08	24,000	14	11	3.7	17,000	0.43
4	<0.08	25,000	10	8.7	1.3	350	<0.08
5	<0.08	100,000	2.7	5.3	3.7	3,500	0.43
6	<0.08	670,000	12	1.7	1.7	20	0.43
			Pseudomonas (Agar F/Centrimide)[a] (cfu)				
1	<11	CS/570	<11	100/<11	CS/<11	3,700	CS
2	<11	CS/730	NS	<11	<11	530/40	CS
3	<11	CS/430	<11	22/<11	<11	500/23	CS
4	<11	670/2,200	11/<11	<11/11	<11	1,800/80	CS
5	<11	20,000/730	22/<11	11	<11/11	900/70	CS
6	<11	1,700/1,900	<11	33/<11	<11	2,300/270	CS
			Coliphage (pfu)				
1	<0.13	380	1.2	0.67	0.53	0.6	<0.13
2	<0.13	960	NS	2.3	<0.13	0.8	<0.13
3	<0.13	530	1.2	0.67	0.27	0.6	<0.13
4	<0.13	990	0.40	0.67	0.27	0.2	<0.13
5	<0.13	1,200	0.40	0.13	0.80	0.4	<0.13
6	<0.13	260	0.67	0.80	0.40	<0.2	<0.13

[a] - Pseudomonas results from Pseudomonas Agar F and Centrimide Agar are both reported; when both methods agreed, the common value is reported.

CS- Contaminated sample.

NS- No sample due to pump malfunction.

TABLE 11. ACTUAL DISTANCE OF SAMPLER STATIONS DOWNWIND OF SAMPLED AREOSOL SOURCE

Aerosol Run No.	Sampler Station Designation		
	Aeration Basin Source		Surge Basin Source
	AB30	AB100	SB50
1	30m	70m	75m
2	40m	90m	70m
3	50m	100m	95m
4	40m	90m	85m
5	50m	100m	85m
6	30m	100m	55m
7	30m		

Note: The actual distance is measured from the edge of the aerosol source to the sampler station, along the straight line that passes through the center of the aerosol source and the center of the sampler station.

For example, it is highly likely that the extremely high Pseudomonas aerosol concentrations obtained downwind of the surge basin were due to contamination of one or both of the high-volume samplers used to collect the samples at SB50.

The downwind distance patterns of fecal streptococci, Pseudomonas, and mycobacteria indicate that wastewater aerosols produced by the DAWTP aeration basins contain many pathogenic bacteria. In addition, the aerosol levels of these pathogenic bacteria at 70 to 100 meters downwind of the aeration basin are generally as high or higher than the levels of such indicator organisms as total coliform and coliphage. Thus, the use of indicator microorganisms such as total coliform or coliphage in wastewater aerosol monitoring appears to be inadequate to characterize the pathogenicity of the aerosols.

Enterovirus Aerosol Levels (Run 7)--

Since the concentrations of human enteroviruses in the DAWTP aeration basin were very low, relative to those of the monitored bacteria and coliphage, special sampling and analytical techniques were necessary to detect enterovirus aerosol levels coming from the aeration basin. Consequently, a special enterovirus aerosol sampling effort (Run 7) was performed. Seven to eight high-volume aerosol samplers were run simultaneously at 30 meters downwind of the DAWTP aeration basin for nine consecutive 30-minute sampling periods, so that a very large volume of air (1980 m^3) was sampled. The collecting fluids from all samplers and all nine sampling periods were combined into one sample (6.185 L), concentrated and analyzed for enteroviruses.

Table 12 shows the wastewater and aerosol concentration data obtained from this enterovirus aerosol run. As can be seen, no enteroviruses were found 30 meters downwind of the DAWTP aeration basin, indicating that the enterovirus aerosol concentration was less than 0.0009 pfu/m^3.

In addition to enteroviruses, the samples of wastewater and aerosol (prior to concentration) were also assayed for the routinely monitored organisms. Except for the Pseudomonas aerosol measurement, the levels on Run 7 were typical or slightly higher than those found on Runs 1 through 6. The high Pseudomonas aerosol concentration obtained from the pooled BHI sample was due to contamination of the same high-volume aerosol sampler used on Runs 1 through 6 at station SB50.

PREDICTION OF AEROSOL EXPOSURE LEVELS

A major aim of the monitoring program was to provide information about the dose of aerosolized microorganism from the DAWTP which the school children at Durham Elementary were likely to be receiving. Since aerosol monitoring at such distances downwind of the DAWTP aeration basin is infeasible, the only means to obtain exposure dose information is by calculation involving a mathematical model, monitoring data, and wind direction data. Quantitative estimates of the peak exposure dose were calculated and are presented in

Table 12. MICROORGANISM AEROSOL CONCENTRATIONS ON ENTEROVIRUS AEROSOL RUN

Microorganism Group	Wastewater Concentration (No./mL)	Aerosol Concentration at AB 30 (No./m^3)
Bacteria (cfu)		
Total Coliform	370,000	32
Fecal Streptococci	4,500	7.3
Mycobacteria	120,000	33
Pseudomonas-Agar F	230	CS
Pseudomonas-Centrimide Agar	1,100	CS
Coliphage (pfu)	1,200	1.5
Enteroviruses (pfu)		
Three-day (HeLa)	0.36	<0.0009
Seven-day (BGM)	0.044	

CS- Contaminated sample

this section. Since the calculation required data extrapolations and assumptions whose validity is uncertain, the estimated peak exposure doses do contain considerable uncertainty.

Estimated Levels During Aerosol Runs

The center of the Durham Elementary classroom area is about 450 meters from the center of the DAWTP aeration basins. To estimate the distribution of microorganism aerosol concentrations at a downwind distance of 450 meters from the aeration basin, the predicted levels at this center line distance were calculated using the microbiological dispersion model[7,4] for each of the six aerosol runs. The general form and parameter estimates for this model were developed from extensive monitoring data obtained at a spray irrigation site in Pleasanton, California.[4] The predictions of the model have been validated for indicator microorganisms based on monitoring programs at two other spray irrigation sites.

A modified form of the microbiological dispersion model was used to represent the DAWTP aeration basin aerosol during each aerosol run:

$$P_d = QD_d \, e^{\lambda a_d} \tag{1}$$

where P_d = predicted microorganism aerosol concentration from the source at a downwind distance d, (cfu/m^3)
Q = aerosol source strength (includes factors for microorganism wastewater concentration, aerosolization rate, and microorganism impact survival), (cfu/s)
D_d = diffusion factor at distance d, (s/m^3)
λ = viability decay rate of the microorganism, (s^{-1})
a_d = aerosol age at distance d, (s), $a_d = d/u$, where u = mean wind speed.

The diffusion factor was normalized to the diffusion value at the AB30 sampler station, $D_d = f_d \, D_{AB30}$, where f_d is the relative aerosol fraction diffusing to distance d. Substituting and taking natural logs,

$$\ln (P_d/f_d) = \ln (QD_{AB30}) + \lambda a_d \tag{2}$$

The viability decay rate λ for the run and the predicted microorganism aerosol concentration along the center line at 450 meters downwind, P_{450}, were estimated by plotting P_d/f_d versus a_d for the AB30 and AB100 sampler stations, on semilog graph paper, and by extrapolating the straight line through these two points to the a_{450} aerosol age. The fractions f_d were estimated from diffusion modeling[8] of sampling runs conducted about a circular spray source at Fort Huachuca, Arizona,[9] having similar dimensions to the DAWTP aeration basin. The f_d values were obtained by overlaying the DAWTP aerosol sampling layout relative to mean wind direction on the normalized diffusion model isopleths for the two modeled runs at Fort Huachuca having the most similar diffusion characteristics.

The model input data are shown in Table 13. The calculated values of the viability decay rate λ and the predicted center line pathogen aerosol concentration at 450 meters downwind, P_{450}, are presented in Table 14.

Each calculation of λ is based on only two points and their microorganism aerosol concentrations are subject to considerable measurement uncertainty. The coefficients of variation due to measurement uncertainty have been estimated[4] as 50 percent for total coliform, 58 percent for *Pseudomonas*, 73 percent for coliphage, 77 percent for fecal streptococci, and 81 percent for mycobacteria. This variability has resulted in some nonnegative decay rates (shown as X's in Table 14), which are actually indistinguishable from a viability decay rate of zero. Clearly, the negative decay rate estimates in Table 14 also contain considerable uncertainty. Since λ is the slope of the line that is extrapolated well beyond the two points in order to obtain P_{450}, this predicted aerosol concentration at 450 meters downwind may be very imprecise. An uncertainty of one order of magnitude in the larger P_{450} values and of several orders of magnitude in the very small P_{450} values is likely.

For Runs 3 and 5, many of the P_{450} values in Table 14 exceed the monitored aerosol concentrations at the AB100 sampling station. Because of treatment facility obstacles (i.e., secondary clarifiers, chemical clarifiers, control building, and chlorine contact chambers), the AB30 and AB100 sampler stations had to be aligned well off the prevailing wind direction from the aeration basin for both of these runs (see Figures F-3 and F-5 of Appendix F). Many organism types also exhibited a viability decay rate of zero during both runs. Thus, it is reasonable to predict a higher aerosol concentration of hardy microorganisms at 450 meters downwind along the centerline than at a 100-meter distance in an infrequent downwind direction.

The distributions of λ and P_{450} obtained from the individual values in Table 14 are summarized in Table 15. Geometric interpolation was used to estimate the 25th, 50th (median), and 75th percentiles of these distributions.

Despite the large uncertainties in individual P_{450} values, the distributions in Table 15 do provide an indication of the typical level and range of aerosol levels to which the school children in the Durham Elementary classrooms are exposed when the classrooms are downwind. The typical levels are quite low, with values of 0.01 cfu/m^3 for the pathogens fecal streptococci and mycobacteria. Since fecal streptococci levels of 0.13 and 0.07 cfu/m^3 were sampled at the upwind station, the typical pathogen levels coming from the DAWTP are probably similar to background levels. However, Table 15 indicates that pathogenic aerosol concentrations considerably above background (approximately 2 cfu/m^3 for fecal streptococci and 5 cfu/m^3 for mycobacteria) may occur in the classroom area about 25 percent of the time that the school is downwind of the DAWTP aeration basin. This interpretation

TABLE 13. AEROSOL RUN MODEL INPUT DATA

Aerosol Run No.	Location/ Distance d	Aerosol Age, a_d (s)	Diffusion Fraction f_d	Microorganism Aerosol Concentration, P_d (cfu/m^3)				
				Total Coliform	Coliphage	Fecal Streptococci	Mycobacteria	Pseudomonas
1	AB30	12	1.00	3.8	0.94	1.2	8.6	
	AB100	28	0.53	0.47	0.53	0.13	0.83	
	450m	180	0.05					
2	AB30	25	1.00	2.3	2.3	2.2	33.	
	AB100	56	0.39	0.20	0.13	0.47	2.8	
	450m	281	0.08					
3	AB30	21	1.00	9.2	0.94	2.9	12.5	
	AB100	42	0.14	2.5	0.27	0.93	3.7	
	450m	188	0.32					
4	AB30	19	1.00	4.1	0.54	1.7	9.3	
	AB100	43	0.35	0.53	0.27	0.33	1.3	
	450m	214	0.10					
5	AB30	9	1.00	7.2	0.27	1.2	4.0	11.
	AB100	18	1.00	3.7	0.80	1.9	3.7	5.5
	450m	80	2.30					
6	AB30	12	1.00	5.7	0.74	2.6	6.9	
	AB100	42	0.25	0.53	0.40	0.73	1.7	
	450m	188	0.045					

TABLE 14. CALCULATED DECAY RATES AND PREDICTED PATHOGEN AEROSOL CONCENTRATIONS

Aerosol Run No.	Total Coliform	Coliphage	Fecal Streptococci	Mycobacteria	Pseudomonas
Viability Decay Rate, $\lambda(s^{-1})$					
1	-0.09	x	-0.10	-0.11	-
2	-0.05	-0.06	-0.02	-0.05	-
3	x	x	x	x	-
4	-0.04	x	-0.02	-0.04	-
5	-0.07	x	x	-0.009	-0.08
6	-0.03	x	x	-0.0002	-
Predicted Centerline Aerosol Concentration at 450m, P_{450} (cfu/m^3)					
1	2×10^{-7}	0.05	5×10^{-9}	2×10^{-8}	-
2	1×10^{-6}	1×10^{-6}	0.001	1×10^{-5}	-
3	4.	0.5	2.	6.	-
4	0.0001	0.07	0.001	0.0007	-
5	0.1	1.	4.	5.	0.1
6	0.0005	0.05	0.1	0.3	-

x Indeterminate viability decay rate: calculated non-negative decay rate was set to zero in calculating P_{450}

Note: All values subject to considerable uncertainty.

TABLE 15. DISTRIBUTION OF DECAY RATES AND PATHOGEN AEROSOL CONCENTRATIONS

	Number of Estimates (Aerosol Runs)	Distribution of Values - Percentiles		
		25%	50%	75%
Viability Decay Rate λ (s^{-1})				
Total Coliform	6	-0.08	-0.05	-0.02
Mycobacteria	6	-0.06	-0.02	-0.0001
Fecal Streptococci	6	-0.04	-0.01	x
Coliphage	6	-0.02	x	x
Predicted Centerline Aerosol Concentration at 450m Downwind, P_{450} (cfu/m^3)				
Total Coliform	6	$7x10^{-7}$	0.0003	0.3
Mycobacteria	6	$2x10^{-6}$	0.01	5.
Fecal Streptococci	6	$5x10^{-5}$	0.01	2.
Coliphage (pfu/m^3)	6	0.004	0.06	0.6

x - Indeterminate viability decay rate, presumably close to zero.

of Table 15 assumes the wastewater quality and meteorological conditions during the week of aerosol sampling are representative of both the mean levels and variability occurring over the two school years of interest.

Making this same assumption, the SB50 sampler data in Table 10 indicate that children playing on the Durham Elementary playground near the surge basin would frequently be exposed to mycobacteria levels of 0.4 cfu/m^3 when downwind of the surge basin. However, their exposure to fecal streptococci would seldom be as high as 0.1 cfu/m^3.

Frequency of Exposure at Durham Elementary

The frequency with which children at Durham Elementary were exposed to aerosols from the DAWTP was investigated. Two aerosol sources at the DAWTP (aeration basins and aerated surge basins) and two exposure locations at the school (classroom area and playground area) were considered. The distances and directions of the exposure locations from the aerosol sources are presented in Table 16.

Students attended Durham Elementary for 178 days in the 1976-77 school year and for 177 days in the 1977-78 school year. Wind direction observations made at Portland International Airport (24 kilometers northeast of the DAWTP) by the Portland Weather Service Office at 7 a.m., 10 a.m., 1 p.m., and 4 p.m. on each of these school days were used in determining the frequency of student exposure.

TABLE 16. ORIENTATION OF EXPOSURE LOCATIONS RELATIVE TO AEROSOL SOURCES

Exposure Locations	Aerosol Source	Distance Range m.	Range of Downwind Directions
Classroom Area	Aeration Basin	330-560	200°-230°
	Aerated Surge Basin	220-310	170°-200°
Playground Area	Aeration Basin	200-500	200°-250°
	Aerated Surge Basin	40-240	160°-230°

A daily exposure index was computed for each exposure location-aerosol source combination, based on the four wind direction observations for the day. If an observation was within the range of downwind directions for the location-source combination given in Table 16, it was given a value of 1.0. Wind direction observations within 30° of this range were considered to represent occasional exposure and given a value of 0.5. The four observation values for the day were then summed to yield the daily exposure index for that location-source combination. Thus, a daily exposure index of 4.0 would indicate steady exposure from the aerosol source throughout the school day, while a daily exposure index of 0.0 would indicate no exposure.

The frequency distributions of the daily exposure index over the 355 school days that the DAWTP was operational are presented in Table 17. On the majority of school days, the classroom area had no exposure to DAWTP aerosols. Seldom was the classroom area steadily exposed throughout the day to aerosolized microorganisms from the DAWTP aerosol sources. Considering daily exposure index values of 3.5 or 4.0 to represent steady exposure, the classroom area was steadily exposed to aeration basin aerosols only on ten days and to surge basin aerosols only on five days. The playground area had a steady exposure to DAWTP aerosols somewhat more frequently, but the number of days is still low.

Table 18 shows the distribution of the daily exposure index by quarter of the school year, for the classroom area from aeration basin aerosols and for the playground area from surge basin aerosols. Days of steady aerosol exposure in the playground area began occurring in December 1976; steady exposure days in the classroom area did not begin until February 1977.

The weather on the days of steady aerosol exposure (index values of 3.5 or 4.0) was reviewed. Periods of rainfall occurred either during or before school on all 14 school days of steady aerosol exposure in the classroom area. These days were characterized by cloudiness (generally overcast), high relative humidity (usually 60 percent to 90 percent), cool temperatures (4°C to 14°C), and frequent steady rainfall. These conditions are conducive to survival of aerosolized microorganisms, but precipitation scavenging during periods of rainfall would reduce the duration of exposure. The weather on days of steady aerosol exposure in the playground area was similar. Based on precipitation during and preceding the school day, the playground was considered usable for student play on only 13 of the 31 school days with steady aerosol exposure.

Microorganism Doses to Which Durham Elementary Students Are Exposed

The preceding sections provide information from which one can infer the likely peak daily doses of airborne microorganisms that the Durham Elementary students may have inhaled while at school. In making this calculation, it is

TABLE 17. FREQUENCY DISTRIBUTIONS OF DAILY EXPOSURE INDEX OF STUDENT EXPOSURE

	Number (N) and Percent (%) of School Days							
Exposure Location:	Classroom Area				Playground Area			
Aerosol Source:	Aeration Basin		Surge Basin		Aeration Basin		Surge Basin	
Daily Exposure Index	N	%	N	%	N	%	N	%
0.0	196	55	191	54	155	44	137	39
0.5	48	14	53	15	58	16	52	15
1.0	35	10	31	9	45	13	44	12
1.5	22	6	27	8	23	6	26	7
2.0	21	6	26	7	23	6	34	10
2.5	13	4	13	4	18	5	21	6
3.0	10	3	9	3	17	5	14	4
3.5	4	1	2	1	8	2	10	3
4.0	6	2	3	1	8	2	17	5

TABLE 18. QUARTERLY FREQUENCY DISTRIBUTION OF STUDENT EXPOSURE

Daily Exposure Index	Number of School Days							
	1976-77				1977-78			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Classroom Area Exposure from Aeration Basins								
0.0	11	30	30	25	6	27	42	25
0.5	2	9	6	6	3	9	7	6
1.0	4	8	8	3	3	3	1	5
1.5	1	5	2	6	1	4	-	3
2.0	-	-	3	3	3	3	5	4
2.5	-	1	2	4	1	2	-	3
3.0	-	1	3	1	2	1	1	1
3.5	-	-	2	-	-	2	-	-
4.0	-	-	2	-	-	3	-	1
Playground Area Exposure from Aerated Surge Basin								
0.0	11	24	18	23	6	15	19	21
0.5	1	10	12	5	1	9	8	6
1.0	4	7	8	4	4	3	9	5
1.5	1	4	3	5	1	3	6	3
2.0	1	1	4	2	2	10	8	6
2.5	-	4	1	4	1	6	3	2
3.0	-	1	4	3	1	1	2	2
3.5	-	2	-	1	2	3	1	1
4.0	-	1	8	1	1	4	-	2

assumed that the wastewater and aerosols sampled during the one-week monitoring period are representative of the levels and variability occurring throughout the two-year DAWTP operational period. Known changes in plant operating procedures and presumed influent variability suggest that such an assumption may be inappropriate. It is further assumed that the extrapolation procedure for estimating P_{450} is valid.

With this caveat, the calculation of the estimated peak microorganism dose received by Durham Elementary students on a single school day during the school year is presented in Table 19. At a breathing rate of 0.25 m^3/hr (see Table 19), the students may have inhaled as many as 9 cfu of mycobacteria and 3.5 cfu of fecal streptococci during seven hours while in the classroom area on the school day on which aerosol exposure was highest. Substantially lower doses are calculated for one hour of playing on the playground downwind from the surge basin. However, because the bacteriological strength of the surge basin wastewater may vary substantially for different batches of wastewater, the peak playground exposure from surge basin aerosols may be considerably underestimated in Table 19.

As a comparison, the usual outdoor background exposure doses can also be calculated, based on the upwind station aerosol samples. During a seven-hour period, the usual background exposure dose would be 0.05 cfu of fecal streptococci and <0.02 cfu of mycobacteria. Hence, the peak exposure dose during a school day may exceed the usual seven-hour outdoor background dose by two orders of magnitude for fecal streptococci, and by perhaps three or more orders of magnitude for mycobacteria.

SCHOOL ATTENDANCE

An analysis was made to determine the magnitude of the potential health hazard posed by the DAWTP to the children attending a nearby school, Durham Elementary, using available school attendance records to measure health status. Durham Elementary's school attendance records before and after the sewage treatment plant's initial operation (July 1976) were examined and compared to the attendance patterns of eight control elementary schools. The purpose of this investigation was to determine whether the attendance data followed a pattern consistent with the research hypothesis that adverse health effects due to the sewage treatment plant were occurring. That is, if subsequent to the operation of the DAWTP the student absenteeism rate at Durham Elementary increased above the baseline years, after adjusting for area-wide effects reflected in the control schools, then it might be attributed to the operation of the sewage treatment plant. Another possible effect of DAWTP operation might be increased absenteeism at Durham after the first several aerosol exposure episodes (perhaps the first two or three quarters of the 1976-77 school year), followed thereafter by normal or reduced absenteeism at Durham as immunity is acquired through repeated exposure.

TABLE 19. ESTIMATED PEAK EXPOSURE DOSE INHALED BY DURHAM SCHOOL CHILDREN [a]

Exposure Location:	Classroom Area	Playground Area	
Aerosol Source:	Aeration Basin	Aeration Basin	Surge Basin
Frequency of Steady Exposure, (days per year)	5	3[b]	5[b]
Duration of Daily Exposure, (hours)	7	1	1
School Child Breathing Rate, (m^3/hr)[c]	0.25	0.43	0.43
Estimated Mean Aerosol Concentration on Peak Day, (cfu/m^3)			
·Fecal Streptococci	2	2	<0.07
·Mycobacteria	5	5	0.4
Estimated Peak Daily Dose Inhaled by School Children (cfu)			
·Fecal Streptococci	3.5	0.8	<0.03
·Mycobacteria	9	2	0.2

[a] Assumes conditions sampled during one week monitoring period reflect both the levels and variability encountered in first two years of DAWTP operation

[b] Excluding days playground not usable due to rain

[c] Assumes an average child body surface area of 1.0 m^2, an at-rest breathing rate of 3.6 L/min/m^2, a classroom rate 15% above at-rest, and playground rate twice the at-rest rate.

TABLE 20. ANNUAL PERCENT ABSENT DATA FOR EACH STUDY SCHOOL

	Baseline Period, %							Period DAWTP Operation, %	
Elementary School	1969-1970	1970-1971	1971-1972	1972-1973	1973-1974	1974-1975	1975-1976	1976-1977	1977-1978
Durham	4.56	5.32	5.69	6.42	5.42	4.85	5.76	4.54	4.80
Control Schools									
Lewis	5.25	5.19	6.03	5.43	5.14	5.41	5.53	5.34	5.77
Metzger	5.09	4.30	5.99	5.68	4.72	4.56	5.38	4.65	5.03
Templeton	5.32	4.09	4.88	4.34	4.36	4.19	4.78	4.39	4.39
Tigard	5.29	4.62	5.76	4.73	4.29	4.27	5.20	4.39	4.84
Tualatin	3.99	4.31	5.19	5.59	4.86	5.60	5.75	4.29	4.24
Bryant	4.49	3.97	4.55	4.55	4.03	4.52	4.99	4.11	4.37
Lake Grove	3.80	4.91	4.39	4.53	4.89	4.32	4.77	4.12	4.42
River Grove	3.92	3.79	4.15	3.92	4.66	3.58	4.47	4.29	3.80
All Control Schools	4.74	4.43	5.95	4.81	4.55	4.52	5.10	4.41	4.57
Five Tigard Control Schools	5.13	4.69	5.56	5.03	4.58	4.67	5.26	4.53	4.74

Analysis by School

School attendance data (total days present, total days absent, and total days membership) were obtained for grades one through six by school, year, and quarter year from 1969-70 through 1977-78 for Durham Elementary and the eight control schools. For the schools in the Lake Oswego School District (Bryant Elementary, Lake Grove Elementary, and River Grove Elementary), only annual totals were available for 1969-70 through 1974-75. The ratio (total days absent)/(total days membership) defining the percent absent was used as the school attendance statistic.

The annual percent absent data for each school during each school year studied is presented in Table 20. Durham Elementary typically encountered 1,000 days of absence and 20,000 days of membership in a school year. Since the control schools had larger enrollments, most control schools typically experienced 3,000 to 5,000 days of absence and 70,000 to 110,000 days of membership per school year. Hence, the percent absent figures reported in Table 20 are all accurate to at least the three significant digits reported.

The annual percent absent values for Durham Elementary and for all eight of the control schools (total days absent divided by total days membership) are plotted in Figure 10 as two time series, with the intervention of initial DAWTP operation in July 1976 indicated. Figure 10 shows that historically, Durham Elementary has tended to have higher levels of absenteeism than the surrounding (control) schools. This high absenteeism rate at Durham Elementary is more evident in the baseline years (1969-70 through 1975-76) than in the operational period (1976-77) through 1977-78). After the DAWTP began operation, the absence percentages at Durham Elementary decreased to lower levels which were similar to those of the eight control schools.

In Table 21, the percent absent in the two-year operational period is compared to the percent absent in the last two years of the baseline period. While a slight decrease in absenteeism occurred at the control schools (-0.32 percent), Durham Elementary had a stronger decrease in absenteeism (-0.69 percent). Figure 10 and Table 21 show improved attendance at Durham Elementary in relation both to the Durham baseline and to the control school pattern. Thus, no evidence of an adverse health effect due to operation of the DAWTP is apparent in the total attendance data at Durham Elementary.

TABLE 21. A COMPARISON OF TWO-YEAR BASELINE AND OPERATIONAL PERIODS

	Percent Absent		
Schools	Baseline 1974/75-1975/76	DAWTP Operational 1976/77-1977/78	Operational Effect
Durham Elementary	5.36	4.67	-0.69
Tigard Control Schools	4.96	4.64	-0.32
All Control Schools	4.81	4.49	-0.32

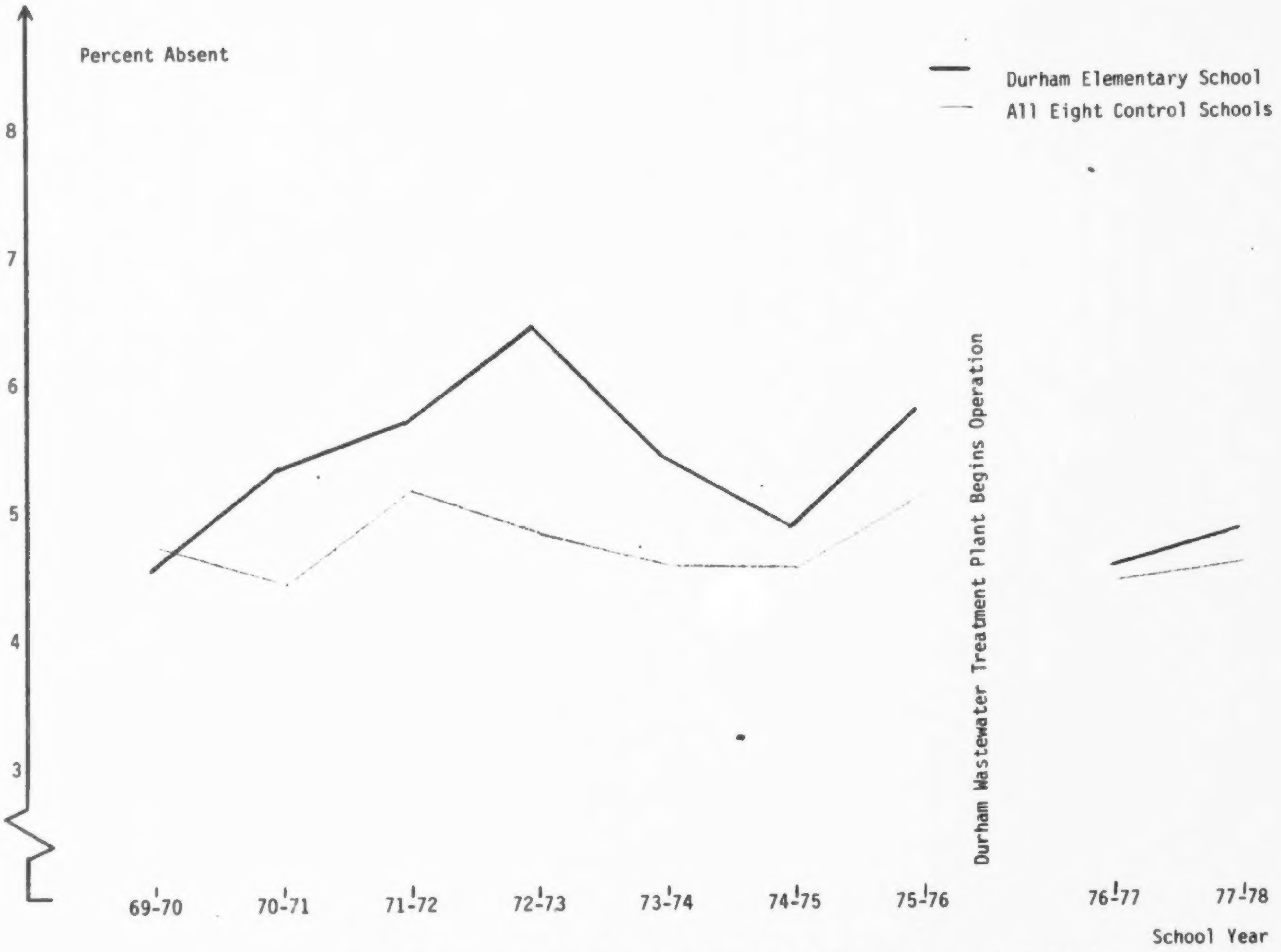

Figure 10. Annual Attendance Plot For Durham and the Control Schools.

The annual percent absent time series plots for each of the nine study schools are presented in Figure 11. While the percent absent at a school showed considerable variation from one year to another, Figure 11 shows that Durham Elementary tended to have a higher annual absence percentage than most of the control schools in the baseline school years (1969-70 through 1975-76). This is especially true of Durham Elementary's attendance in 1970-71, 1972-73, 1973-74, and 1975-76. It should be noted that school attendance during the 1975-76 school year was worse than in the preceding and following school years, not only for Durham Elementary but also for each of the eight control schools. This indicates the existence of area-wide effects, such as inclement weather or severe "flu" seasons, that differ in magnitude from one year to the next.

Figure 11 also shows that the attendance patterns of the three control schools in the Lake Oswego School District (Bryant, Lake Grove, and River Grove) were almost consistently better (i.e., lower percent absent) than those of the five control schools in the Tigard School District. The Lake Oswego School District is generally considered to be one of the "prestige" districts in the Portland area. Furthermore, the Bryant, Lake Grove, and River Grove students live in a more settled (completely developed) residential area of more uniformly high socioeconomic status than do the Tigard School District students. Thus, these three Lake Oswego schools may be less similar to Durham Elementary than are the other five Tigard District schools. Consequently, only the other five Tigard schools were used as controls for Durham Elementary for the remainder of the school attendance analysis.

Figure 12 contrasts the annual percent absent time series for Durham Elementary with the time series for the five control schools in the Tigard School District. By excluding the attendance data of the Lake Oswego School District in Figure 12, the magnitude of the difference between absenteeism at the Durham Elementary and the control schools has been reduced. However, the same general features remain. Durham Elementary continues to have a higher annual absence percentage than the control schools, especially in most baseline school years. However, after the operation of the DAWTP, the absence percentage at Durham Elementary was very close to the level of the five control schools. The comparison of two-year baseline and operational period absenteeism in Table 21 confirms the pattern. While there is virtually no difference in percent absent during the operational period (4.67 percent at Durham Elementary versus 4.64 percent at the Tigard control schools), Durham showed more than twice the improvement in attendance in the operational period (absences down 0.69 percent at Durham versus only 0.32 percent at the control schools). Again, the annual attendance data for grades one through six provide no evidence of a persistent adverse health effect due to operation of the DAWTP.

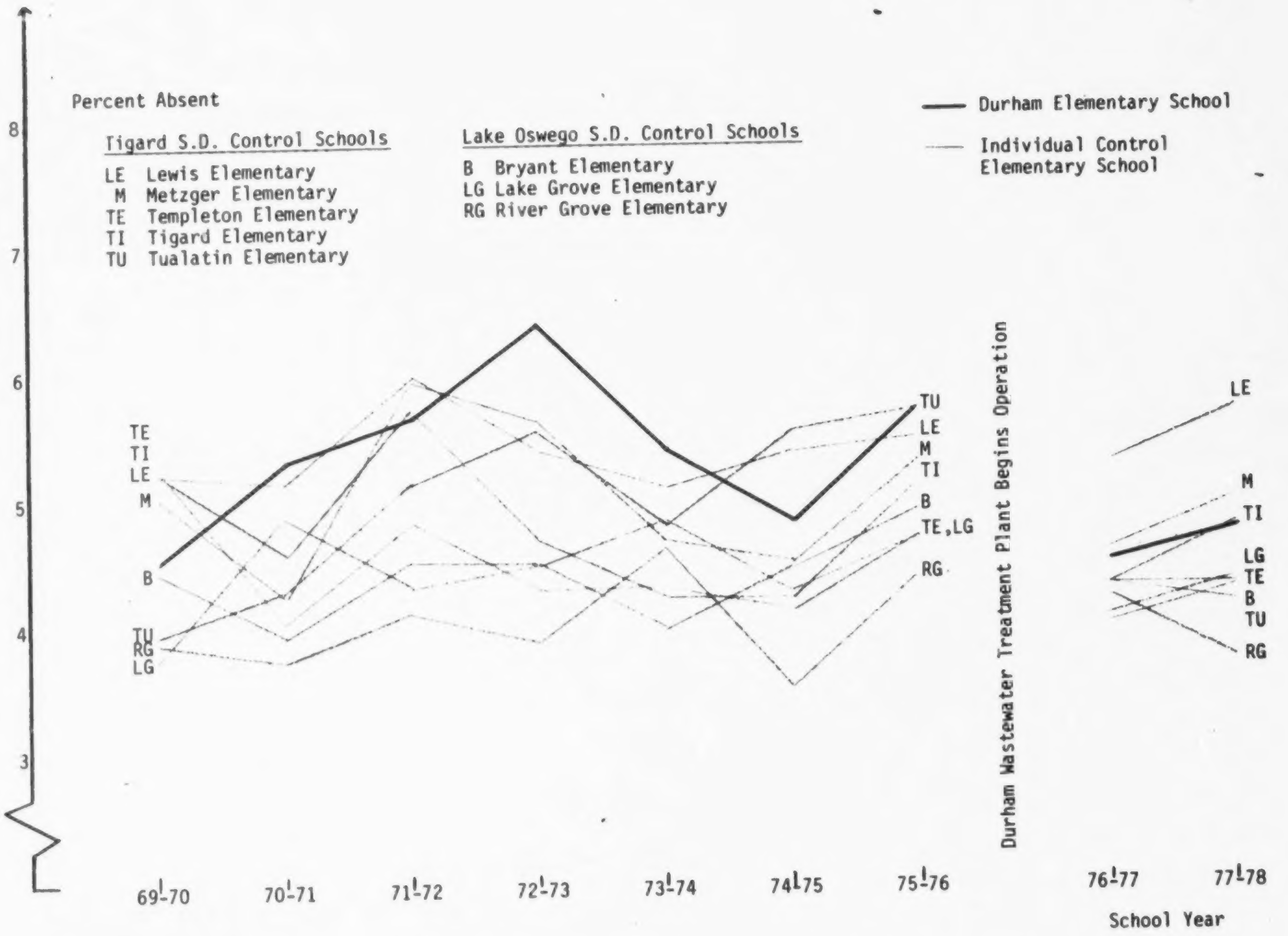

Figure 11. Annual Attendance Plot for the Individual Schools.

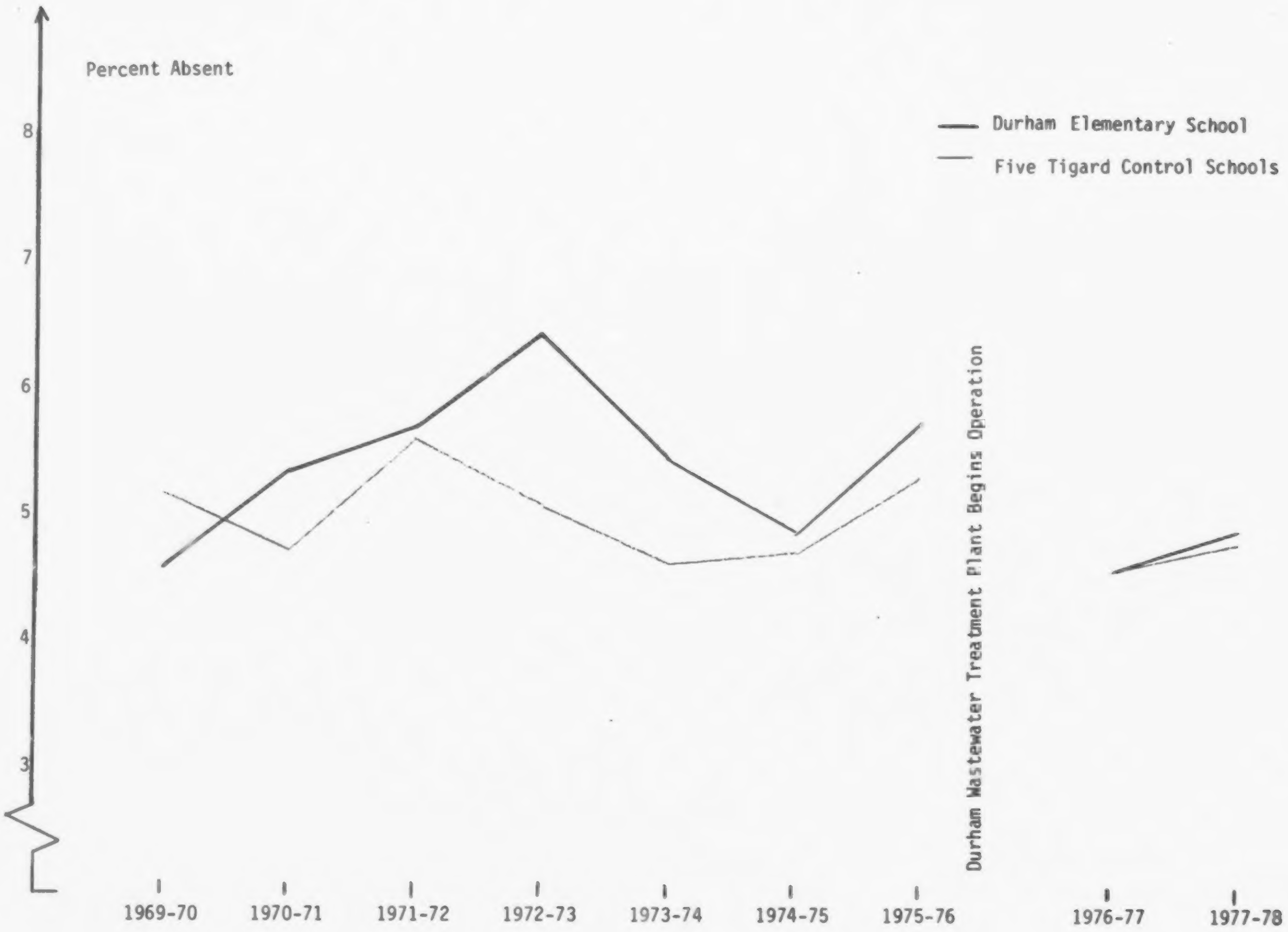

Figure 12. Annual Attendance Plot for Durham and the Tigard Control Schools.

Figures 10 through 12 suggest that factors other than DAWTP operation are primarily responsible for the differences that occurred in the school attendance patterns at Durham Elementary and the control schools. Similar changes in pattern, such as the increased absenteeism that occurred at each of the schools in 1975-76, are obviously due to longitudinally varying factors of area-wide effect, such as communicable disease epidemics or periods of severe weather. However, more school-specific factors are also evident from the school-to-school variability depicted in Figure 11. A possibly significant factor at Durham Elementary were the changes in principal. After the perennial principal at Durham retired in July 1974, a second principal remained two years and was followed by a third principal in July 1976, coinciding with the opening of the DAWTP. A comparison of school attendance under the three principals is presented in Table 22. School absenteeism declined with each succeeding principal: from 5.50 percent absent under the first principal to 5.36 percent under the second principal and to 4.67 percent with the third principal. Adjusting for area-wide factors via the Tigard control schools shows a 0.50 percent excess under the first principal, a 0.40 percent excess under the second, and only a 0.03 percent excess under the third principal. Hence, changes in principal may have contributed to the recent improvement in school attendance at Durham Elementary.

To examine more transitory health effects, quarterly time series of percent absent at Durham Elementary and the combination of the five Tigard control schools are presented in Figure 13. There is a very pronounced seasonal pattern with the lowest percentage of absences in the first quarter (September) and the highest absence rate usually in the third quarter (January-March). Likely factors leading to poorer attendance, especially in the third quarter of a year, are communicable diseases such as cold and flu-type illnesses and rainy weather conditions which usually occur during the winter months in the Portland area.

TABLE 22. ASSOCIATION OF SCHOOL ATTENDANCE WITH PRINCIPAL CHANGES AT DURHAM ELEMENTARY

		Percent Absent		
Durham Principal	School Years From To	Durham Elementary	Tigard Control Schools	Difference at Durham
First	1969/70-1973/74	5.50	5.00	+0.50
Second	1974/75-1975/76	5.36	4.96	+0.40
Third	1976/77-1977/78	4.67	4.64	+0.03

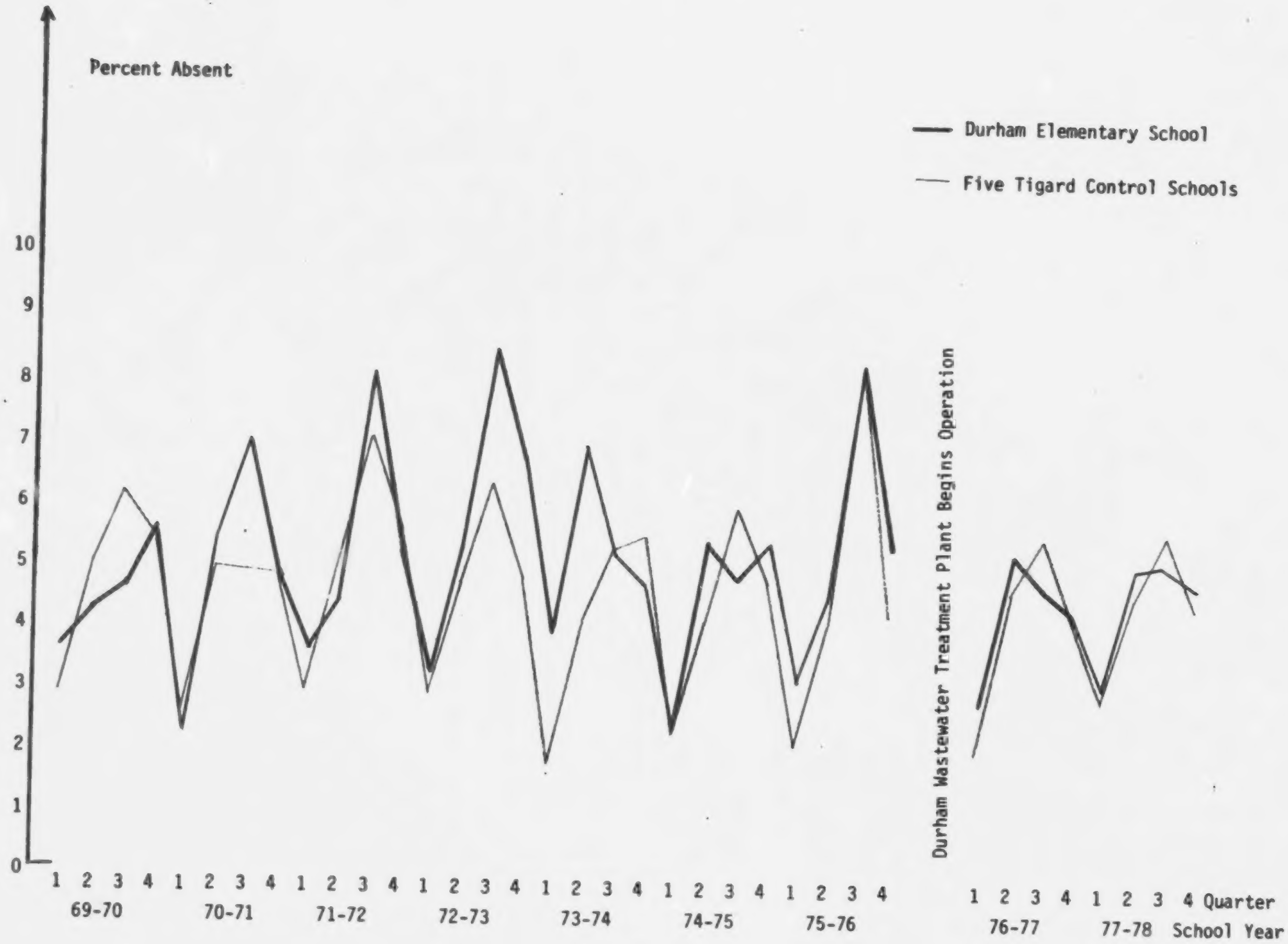

Figure 13. Quarterly Attendance Plot for Durham and the Tigard Control Schools.

Figure 13 shows that Durham Elementary's absence percentage differed from the pattern of the Tigard control schools on several occasions. The marked deviations all occurred during the baseline period and are summarized below:

Period	Higher Percent Absent
2Q through 3Q, 1969-70	Tigard control schools
2Q through 3Q, 1970-71	Durham Elementary
3Q, 1972-73 through 2Q, 1973-74	Durham Elementary

To examine the quarterly differences between Durham Elementary and the control schools in the context of school-to-school variability, the quarterly time series for each school are displayed in Figure 14. As in Figure 13, the most pronounced deviation was the continually higher absence percentage at Durham Elementary during all four quarters of calendar year 1973.

Because of the time lag after initial viral exposure before antibody levels will provide immunologic protection, the most pronounced effect of the DAWTP on Durham Elementary School attendance due to viral aerosols might be expected to occur in the first two or three quarters of the 1976-77 school year. Figures 13 and 14 do suggest a very slight elevation in absenteeism at Durham Elementary (relative to the control schools) during these first two quarters, followed by a slight relative improvement in absenteeism during the rest of the DAWTP operational period. However, this pattern is extremely small in comparison to the huge deviations occurring in the baseline period. It is no larger than many slight discrepancies occurring throughout the baseline period. Hence, the very slight elevation in absenteeism at Durham Elementary during the first two quarters cannot be considered an unusual occurrence.

Analysis by Class Cohorts

The preceding analysis does not rule out the possibility of adverse health effects from DAWTP operation on some Durham class cohorts which is obscured in the grouped data for grades one through six. Consequently, attendance data was obtained for each grade at Durham Elementary and the two nearest Tigard District control schools, Templeton and Tualatin, for each quarter of the seven schools years 1971-72 through 1977-78.

These attendance data are summarized by school and grade in Table 23. There is a very slight tendency for absenteeism to decrease as children progress from first grade through sixth grade. Also, Durham Elementary had a higher rate of absenteeism over the seven school years than did the control schools (Templeton and Tualatin). Both of these factors should be considered when analyzing the data by class cohorts.

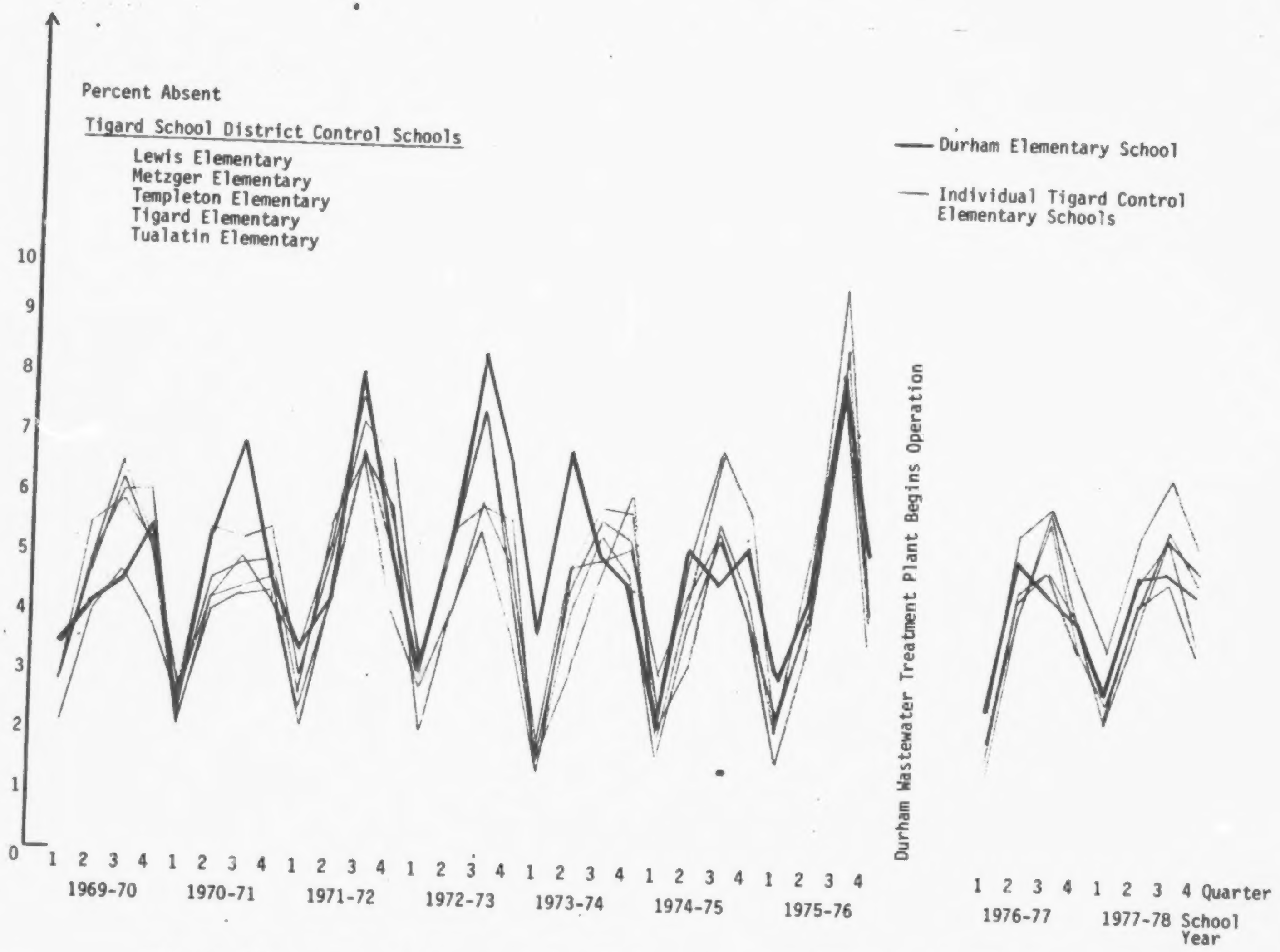

Figure 14. Quarterly Attendance Plot for the Individual Tigard Schools.

TABLE 23. ASSOCIATION OF ABSENTEEISM WITH GRADE LEVEL

	Percent Absent Over Seven School Years, (1971-72 through 1977-78)			
	Durham	Templeton	Tualatin	All Three Schools
First Grade	6.06	4.96	5.29	5.21
Second Grade	6.01	4.64	4.97	4.92
Third Grade	4.95	4.47	4.85	4.66
Fourth Grade	5.18	4.46	4.74	4.64
Fifth Grade	5.14	4.27	5.27	4.69
Sixth Grade	4.77	4.27	4.80	4.49
Grades 1-6	5.35	4.50	4.99	4.76

The quarterly attendance data for each Durham class cohort and its control (Templeton plus Tualatin) class cohort are presented as a set of time series plots in Appendix G. Several intervals of marked discrepancies between the Durham and control class cohorts occurred during the baseline period, as summarized below:

Cohort	Discrepancy Interval	Higher Absenteeism
Entered grade 5 in 1971-72	3Q, 71-72 thru 4Q, 72-73	Durham
Entered grade 3 in 1971-72	1Q, 72-73 thru 4Q, 73-74	Durham
Entered grade 1 in 1971-72	3Q, 72-73 thru 2Q, 73-74	Durham
Entered grade 1 in 1972-73	4Q, 74-75 thru 1Q, 76-77	Durham

The first three discrepancies occurred over roughly the same time interval and account for the prolonged discrepancy noted in the analysis by school.

Several intervals of slighter discrepancies between class cohorts occurred in the DAWTP operational period:

Cohort	Discrepancy Interval	Higher Absenteeism
Entered grade 1 in 1975-76	4Q, 75-76 thru 4Q, 76-77	Durham
Entered grade 1 in 1976-77	2Q, 76-77 thru 1Q, 77-78	Durham
Entered grade 1 in 1977-78	2Q thru 4Q	Durham

It should be noted that the higher absenteeism occurring after DAWTP operation at Durham happened among the younger children (in first and second grade at the time). However, except for 2Q in the cohort entering first grade in 1977-78, the percent absent at Durham during these periods did not exceed seven percent. In four of the five baseline years, the first grades and/or second grades at Durham had at least one quarterly absentee rate above eight percent. Hence, it is questionable whether the DAWTP had even a slight adverse effect on absenteeism among students in the first and second grades at Durham Elementary.

SECTION 7

DISCUSSION

MONITORING OF WASTEWATER AND AEROSOLS

Comparison of the wastewater concentrations of the routinely-assayed microorganisms shows a consistent difference between the large volume samples (Table 6) taken in November 1977 and the routine monitoring samples (Table 9) taken in March 1978. In samples taken from the aeration basin, the microorganism levels were much lower in the large volume sample than in the routine monitoring samples (e.g., 1,800 cfu/mL versus 450,000 cfu/mL for total coliform). However, in samples taken from the surge basin, the microorganism levels were somewhat higher in the large volume sample (e.g., 1,100 cfu/mL versus 44 cfu/mL for total coliform). While less extreme, this same pattern was also evident for fecal streptococci and mycobacteria. The large volume aeration basin sample also had much lower concentrations of Pseudomonas and coliphage than did the routine monitoring samples from the aeration basin.

There are at least two possible explanations for this observation. First, during the November sampling period, considerable quantities of wastewater were being returned to the aeration basin from the surge basin, thus diluting the time-composite sample. This was not the case during the March sampling period. Second, the large volume samples taken in November were 24-hour time-composite samples, whereas the March samples were short-term (i.e., 30-minute) samples taken during periods of the day when the influent being treated might be expected to have the highest microorganism levels.

Microorganism concentrations in wastewater have also been monitored recently from the primary aeration basin at the Egan sewage treatment plant, Schaumburg, Illinois,[2] and from the aerated effluent holding pond of the Pleasanton sewage treatment plant, Pleasanton, California.[4] The DAWTP aeration basin and surge basin results from the routine wastewater monitoring are contrasted with the comparable Egan and Pleasanton results in Table 24. The DAWTP aeration basin was generally quite similar to the Egan primary aeration basin in the concentrations of most monitored

TABLE 24. SITE COMPARISON OF MICROORGANISM CONCENTRATIONS IN WASTEWATER BEFORE AEROSOLIZATION

	Geometric Mean of Wastewater Sample Assays (No./mL)			
	Durham Plant[a]		Egan Plant Primary Aeration Basin	Pleasanton S.T.P. Effluent Pond
	Aeration Basin	Surge Basin		
Total Plate Count	4,800,000[b]	210,000[b]	5,900,000	610,000
Total Coliform (cfu)	450,000	44	400,000	7,100
Fecal Streptococci (cfu)	4,500	5.3	740	62
Mycobacteria (cfu)	59,000	320	1,000	46
Pseudomonas (cfu)			8,600	2,600
·Agar F	1,500	1,200		
·Centrimide Agar	930	130		
Coliphage (pfu)	690	0.3	120	275
Enteroviruses (pfu)	0.50	0.0019	0.13	0.033

[a] Excludes large volume samples (except for total plate count).

[b] Based on single large volume sample.

microorganisms in the mixed liquor. Since the physical conditions at the two sites were also similar, this observation confirms our expectation. The wastewater in the DAWTP surge basin tended to have much lower microorganism concentrations than either of the aeration basins, and somewhat lower microorganism levels than the Pleasanton effluent pond. The major exception was mycobacteria, which was much more prevalent in the DAWTP wastewater than at the other sites.

Aerosol microorganism concentrations downwind of the Durham and Egan aeration basins and the line of sprinklers at the Pleasanton spray irrigation site are presented in Table 25. Because of the prevalence of mycobacteria in the Durham wastewater, the mycobacteria aerosol levels were higher at the DAWTP aeration basin than at the other study sites. Coliphage and fecal streptococci aerosol levels were also somewhat higher at short downwind distances at the Durham site.

TABLE 25. SITE COMPARISON OF AEROSOL MICROORGANISM CONCENTRATIONS AT 30 TO 50 METERS DOWNWIND OF AEROSOL SOURCE

	Geometric Mean of Aerosol Concentrations (No./m^3)		
	Aeration Basin Source		Sprinkler Source
	Durham Plant	Egan Plant[a]	Pleasanton[a]
Total Coliform (cfu)	5.8	7.1	2.4
Fecal Streptococci (cfu)	2.0	<2.	0.61
Mycobacteria (cfu)	9.1	---	0.8
Pseudomonas (cfu)	7.	40.	34.
Coliphage (pfu)	0.71	0.03	0.38
Enteroviruses (pfu)	<0.0009	<0.01	0.014

[a] Data for samplers at 50 meters downwind of aerosol source.

No aerosolized enteroviruses were detected downwind of the DAWTP aeration basin on the enterovirus aerosol run, despite the large volume of air sampled. Hence, the enterovirus aerosol concentration was less than 0.0009 pfu/m^3. This result is not surprising. The data in Table 9 indicate that only 2.1 percent (geometric mean of sample percentages) of the enteroviruses found in the DAWTP aeration basin wastewater were in the liquid fraction of the wastewater. This agrees very well with the 2.0 percent of wastewater enteroviruses found to be in the liquid fraction at the Egan site. Thus, 98 percent of the wastewater enteroviruses were adsorbed onto or incorporated into the mixed liquor suspended solids in the aeration basin. Consequently, these enteroviruses are less likely to become or remain aerosolized to downwind distances of even 30 meters, because of the large particle size.

The distributions of microorganism viability decay rates shown in Table 15 for the DAWTP aeration basin aerosol can be compared to the viability decay rate distributions of the same organisms obtained for the Pleasanton spray irrigation aerosol. These comparisons are presented in Table 26. From the distribution percentiles, it appears that viability decay at Durham differed somewhat from the Pleasanton pattern (i.e., more rapid decay of mycobacteria and fecal streptococci and less rapid decay of coliphage). Two nonparametric statistical tests were conducted to test the null hypothesis of no difference in viability decay between sites against the two-sided alternative. These were the two-sample Kolmogorov-Smirnov test[10] of cumulative distribution functions to examine distributional differences and the signed ranks test[11] to detect shifts in location. At the 0.10 significance level, no significant differences between sites were found for any microorganism by either test. The inability to detect significant differences in the viability decay distributions at Durham from those at Pleasanton may reflect either the small Durham sample size (i.e., six aerosol runs), the wide variability of individual estimates, or the lack of any site difference. Nevertheless, use of the Durham percentiles instead of the Pleasanton percentiles of viability decay would substantially alter the predicted aerosol concentration P obtained from the microbiological dispersion model at downwind distances beyond several hundred meters.

The Pleasanton data ranked fecal streptococci and mycobacteria as having less viability decay than coliphage, which survived only slightly better than total coliform. However, the Durham ranking showed coliphage with less viability decay than fecal streptococci and mycobacteria. Since the Durham ranking of these microorganisms is not statistically significant, the Pleasanton and Durham rankings of microorganism viability decay are not necessarily inconsistent.

Using the microbiological dispersion model predictions for the Durham aerosol runs, the highest dose of aerosolized microorganisms from the DAWTP inhaled in one school day by the Durham Elementary students was estimated to

TABLE 26. SITE COMPARISON OF VIABILITY DECAY RATE DISTRIBUTIONS

Microorganism	Site	Number of Estimates	Viability Decay Rate $\lambda(s^{-1})$ Distribution of Values - Percentiles			Significant Difference Between Sites?[a]
			25%	50%	75%	
Total Coliform	Durham	6	-0.08	-0.05	-0.02	No
	Pleasanton	44	-0.09	-0.03	-0.004	
Mycobacteria	Durham	6	-0.06	-0.02	-0.0001	No
	Pleasanton	8	-0.009	X	X	
Fecal Streptococci	Durham	6	-0.04	-0.01	X	No
	Pleasanton	31	-0.006	X	X	
Coliphage	Durham	6	-0.02	X	X	No
	Pleasanton	43	-0.05	-0.01	X	

X - Indeterminate viability decay rate, presumably close to zero.

[a] - Based on the two sample Kolmogorov-Smirnov test of cumulative distribution functions and on the signed ranks test of shifts in location, both at the 0.10 significance level.

be about 9 cfu of mycobacteria and 3.5 cfu of fecal streptococci. These peak exposure doses exceed the usual background dose by about two orders of magnitude for fecal streptococci and by perhaps three or more orders of magnitude for mycobacteria. Since the calculation required data extrapolations and assumptions whose validity is uncertain, these peak exposure doses do contain considerable uncertainty. The importance of these peak microorganism dosage values is that they provide a rough estimate of the dosing level against which to evaluate the health response measured by school attendance.

EFFECTS ON SCHOOL ATTENDANCE

In the two school years after the DAWTP began operating, annual school attendance at neighboring Durham Elementary School improved. The improvement at Durham was evident in comparison both to prior school attendance at Durham and to school attendance in the surrounding control schools. Hence, there is no evidence that operation of the DAWTP had any sustained adverse effect on school attendance at Durham Elementary.

Analysis of the school attendance data on a quarterly basis also yielded no evidence of adverse effects having a shorter duration. However, very occasional transitory effects could not have been identified from the quarterly attendance data available for this study.

The analysis of class cohorts showed some extended periods of elevated absenteeism among first and second grade students at Durham Elementary (compared to the control school cohorts) after operations at the DAWTP commenced. However, periods of even higher absenteeism among first and second grade students at Durham Elementary also characterized many of the baseline years. Thus, it is uncertain whether the absenteeism among the younger students at Durham Elementary had any relationship to DAWTP operation.

This study illustrates both the advantages and disadvantages of using elementary school attendance data for an epidemiologic investigation of a localized potential health hazard. The advantages are the uniformity, availability, and copious volumes of school attendance data, which permit the detection of many significant differences. The primary disadvantage is the existence of many potentially-confounding factors affecting school attendance which are unrelated to student health and which can obscure the potential hazard being investigated. Elsbree and McNally[12] emphasize that school attendance is affected by school factors under the principal's and teachers' control (e.g., policies regarding student progress, nature of curricular and extracurricular activities), as well as student factors (e.g., personal illness, sickness in family, work at home, poverty, inclement weather, parental indifference, travel distance in rural schools). While personal illness is one of the leading causes of absence, other factors may also have sizable effect. Hence, school attendance is quite an insensitive measure of adverse health effects. The lack of an effect on school absenteeism does not necessarily imply the absence of any health hazard.

There were three principals at Durham Elementary during the school attendance study period. The third principal served only during the two DAWTP operational years, so the effects of his policies on school attendance are confounded with those of the DAWTP. This change in principal may have been responsible for part of the improvement in attendance at Durham Elementary in the DAWTP operational years.

There were few school days during the two years of DAWTP operation when the wind blew steadily from the southwest and south to provide prolonged student exposure to microorganisms in the wastewater aerosol. Furthermore, prolonged periods of rainfall occurred on many of these steady downwind days, reducing both the duration of exposure and the extent of outdoor activity. Hence, the Durham students probably received the predicted peak daily doses (9 cfu of mycobacteria and 3.5 cfu of fecal streptococci) about one school day per year. These peak doses may exceed the usual outdoor background doses by perhaps three or more orders of magnitude for mycobacteria and by about two orders of magnitude for fecal streptococci. Such dose increases are relatively small compared with the dosage ranges used in controlled dose-response studies on animals. At this dosing level and frequency, no clear evidence of adverse health effects could be detected in the Durham Elementary students when using the relatively insensitive school absenteeism measure.

As originally conceived, the study results were to be used to evaluate the need for a more complete epidemiologic investigation of the school children and other populations living near the DAWTP. Such a health effects study might involve health diaries, a serosurvey, and illness monitoring using clinical specimens. The study results (i.e., no preliminary evidence of an adverse effect based on school attendance, apparently typical aerosol levels from the aeration basin, and low aerosol levels from the surge basin) do not suggest a health hazard exists. Considering these results in light of the limited available funding for health effects studies, further epidemiologic investigation of health effects around the DAWTP does not appear to be warranted at this time.

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APPENDIX A

PROCEDURES FOR OPERATING A PAIR OF HIGH-VOLUME AEROSOL SAMPLERS DURING AN AEROSOL RUN

1. After sampling sites have been selected and assigned, set up two sample tables 1m* apart. Check the tables to make sure they are level. Set a generator off to the downwind side the full length of the extension cord and check the gas and oil levels before starting. Set the samplers in the center of each table with the control panel on the downwind side.

2. Place a piece of masking tape on a BHI media bottle and mark the level of the liquid. Run the media into the high-volume sampler and when the media returns to the bottle, mark the liquid level on the BHI bottle again. Keep the level of the liquid at this second mark throughout the run by adding sterile water as is necessary. Keep the BHI bottle covered with its lid and masking tape during the run.

3. Make sure that the plate is wetting properly and then set the liquid flow rate at 3-6mL/min. Adjust the air flow rate to read the calibrated 1000L/min mark.

4. After 3 minutes of BHI media recirculation, turn the high-voltage power supply to 14 kv and sample for 30 minutes unless instructed differently. Pay careful attention to the liquid levels of the BHI and to excessing arcing.

5. At the end of the 30 minutes, turn off the high-voltage power supply and pull the supply line out of the BHI reservoir. Run the liquid pump and the air blower until all the liquid has been collected in the original bottle. Make the level up to the original 100mL mark on the bottle with sterile water.

6. Clean up the samplers either in the field or the lab as instructed.

* See text - Section 5, Methods and Materials

APPENDIX B

PROCEDURE FOR DECONTAMINATION OF HIGH-VOLUME AEROSOL SAMPLERS

Solutions: 1% Clorox®

Buffers - KH_2PO_4 (136g/L) 26.1mL L DI H_2O
Na_2HPO_4 (142g/L) → 40.5mL

Autoclave 50mL of buffer in 2 oz. bottles

Add 1mL of 5% Clorox® prior to use

1% Sodium Thiosulfate

10g Na Thio/L DI H_2O

Autoclave 100mL in 4 oz. bottles prior to use

Sterile water

Autoclave 100mL in 4 oz. bottles prior to use

Procedure:

Initial Cleanup

1. Calibrate air flow meter for 1000 lpm.
2. Disconnect electrical supply, remove side plates from unit.
3. Using Kim Wipes dipped in 100% ethyl alcohol, wipe the inside top half sides and all upper section parts. Dry with clean Kim Wipes.
4. Run disc (but not blower) and pump 1% Clorox® solution through all tubes. Small amounts of the solution may be poured on the top of the disc to speed up the cleaning procedure.
5. After decontamination with Clorox® solution, flush the system with the contents of a sodium thiosulfate bottle.
6. Rinse the system with the contents of a sterile water bottle. Place 5 drops of the last 10mL of H_2O fluid from the outlet tube on a TGY plate. Incubate at 37°C for 48 hours and check for colonies.
7. After most of the liquid has been pumped out of the system, attach a microfilter to the sampler inlet and run the blower until the disc is dry.
8. Place the ends of the tubes in a clean plastic bag and tape shut.

Seal the sampler inlet and exhaust ports with aluminum foil.

Subsequent Cleanup: After the initial cleanup, steps 4 through 8 are sufficient for future decontamination provided no contamination is indicated by the TGY plates.

APPENDIX C

DESCRIPTION OF LITTON MODEL M HIGH-VOLUME AEROSOL SAMPLER

"The Model M Sampler is designed to continuously collect particulate matter from a large volumetric flow rate of air (approximately 1000 liters/minute) and deposit it into a small amount of liquid (flow rate of 2mL/min). This effects a volumetric concentration factor on the order of 5 x 10^5. Basically, the sampler is an electrostatic precipitator of a rather unusual configuration. With reference to the schematic diagram, Figure C-1, and an interior view, Figure C-2, aerosol is drawn into the unit through a converging nozzle and passes through the center of the high-voltage plate. It then flows radially between this plate and a lower rotating collection disc. An electric potential of 15,000 volts, which is maintained across a 11/16-inch spacing between the plate and disc, creates two effects: (1) A corona is emitted from a ring of 60 needles that is located concentric to the air inlet. Particles, exposed to air ions created from the corona, acquire an electrical charge. (2) The electric field provides the driving force to precipitate charged particles onto the lower disc.

"Liquid is pumped onto the center of the collection disc and, because of the centrifugal force, forms a thin moving film over the entire disc surface. Particles collected on the film are transported to a rotating collection ring where the liquid is removed by the pickup. Subsequently, the liquid drips into the collection funnel where it is pumped to a receiver located outside the sampler.

"To accommodate a broad range of sampling situations, several variable features are incorporated into the unit. These are:

Air Flow Rate	400 to 1200 liters/minute
Liquid Flow Rate	0 to 8mL/minute
Disc Speed	0 to 45 rpm
High Voltage	0 to 20 kilovolts

"When the sampler is in operation, the air flow rate is read directly from a calibrated meter on the front panel and is adjusted with a blower control potentiometer (see Figure C-3). Both disc speed and pump flow rate are controlled by high and low range toggle switches, together with potentiometers. Although no direct readouts are provided for these two variables, calibrations are easily obtained so the arbitrary scales on the potentiometers can be converted to actual

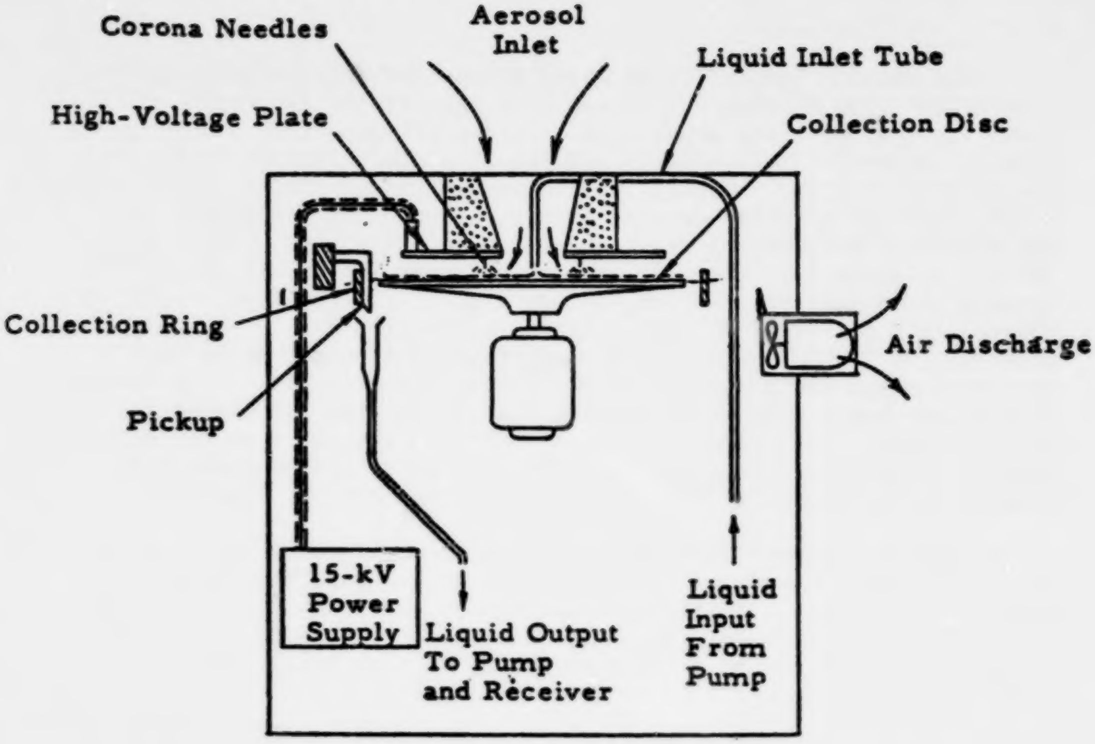


Figure C-1. Schematic Diagram of Large-Volume Air Sampler System

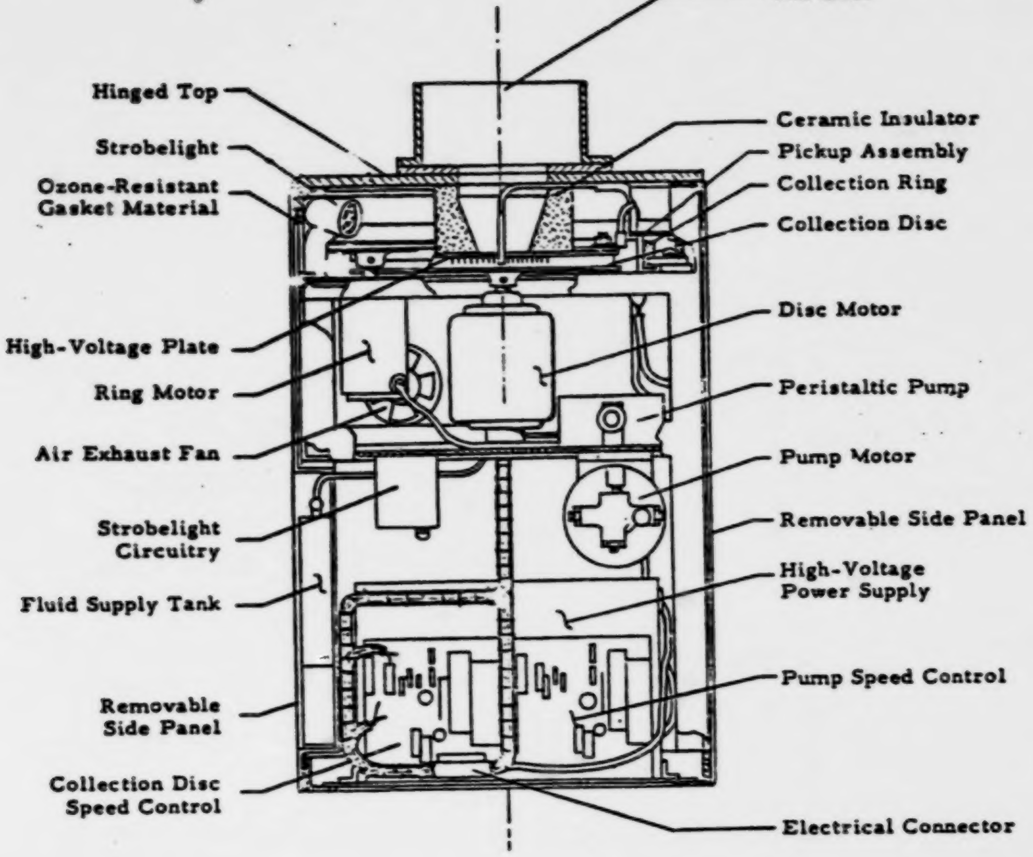


Figure C-2. Interior View of Large-Volume Air Sampler

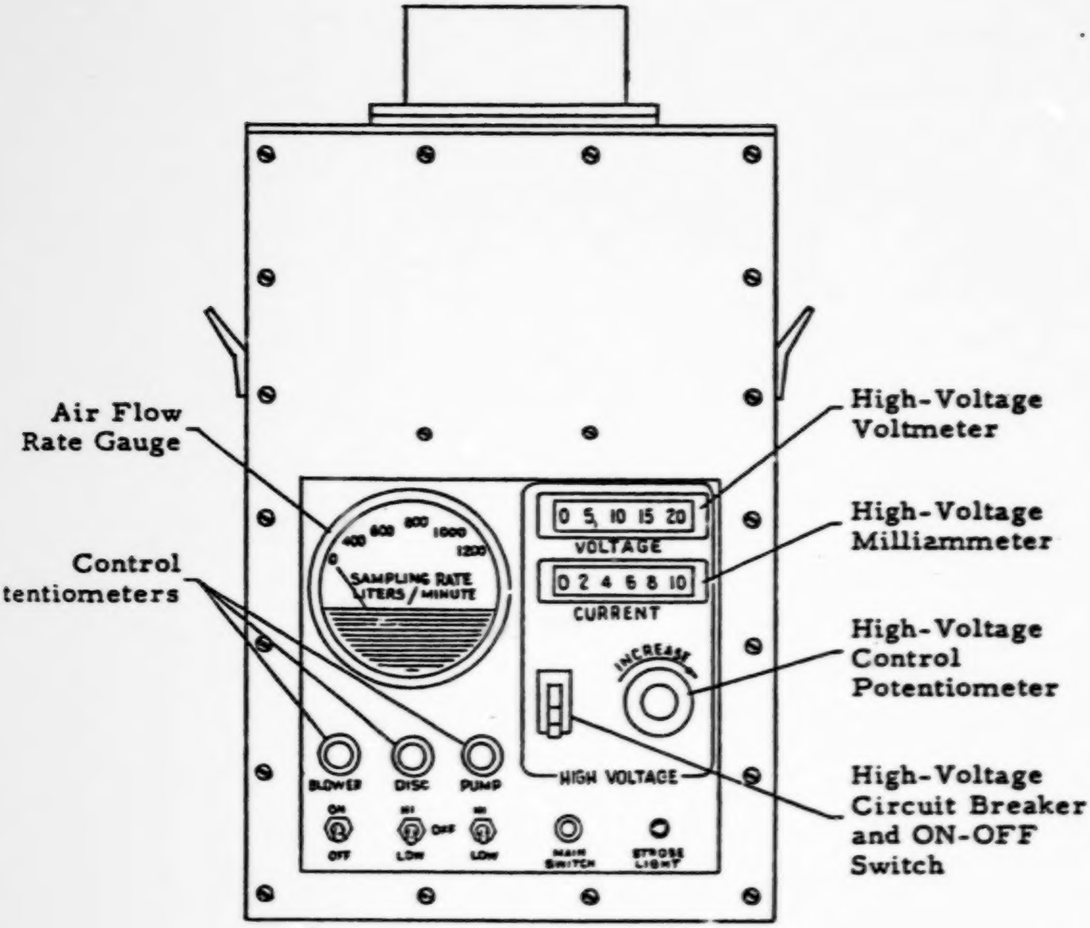


Figure C-3. Instrument Panel of Model M Large-Volume Air Sampler speed or flow rates. The high-voltage system is set with the aid of a potentiometer and is provided with the meter to show voltage and current."[1]

To facilitate visual observation of the surface condition of the disc in operation, the operator made observations through the windows with the aid of a flashlight. The air flow rate was set at 1000 liters/minute.

---

[1] Litton Model M Large-Volume Air Sampler: Instruction Manual, Report No. 3028. Minneapolis, Minnesota (1966).

APPENDIX D

PHASE-SEPARATION METHOD FOR CONCENTRATION OF ENTEROVIRUSES FROM AEROSOL SAMPLES

Reagents:
20% (w/w) Dextran sulfate, sodium salt (Pharmacia)
30% (w/w) Polyethylene glycol 6000 (Union Carbide)
5 M NaCl

Procedure:

1. Measure volumes of BHI with 0.1% Tween 80® to be concentrated (±10 mL) and transfer to separatory funnel.

2. Add volumes of reagents specified in the table below in the following order; sodium dextran sulfate, PEG, NaCl.

Sample Size (mL)	20% Na-DS* (w/w)	30% PEG 6000* (w/w)	5M NaCl*	Total Vol (mL)
500	6.7mL	145mL	20mL	672
1000	13mL	290mL	41mL	1344
1500	20mL	435mL	61mL	2016
2000	27mL	580mL	82mL	2689

* Final concentrations: 0.2% Na-dextrane sulfate, 6.45% PEG 6000, 0.15M NaCl.

3. Shake the total volume vigorously to facilitate total mixing of polymers and sample. Place separatory funnel at 4°C to allow phase separation.

4. After 18 hr, phase separation will be ±95% complete. Three partitioned volumes may be observed: upper phase, interphase, and lower phase. (The volume of interface may not be significant, depending upon constituents present in original test sample.) Collect lower phase and interphase volumes in sterile centrifuge tubes avoiding channelization as much as possible. (Remember to remove stopper from funnel.) If interface volume contains solids/debris, collect it separately to avoid microbial contamination of lower phase.

5. Store collected volumes at 4°C.

6. Disinfect remaining phase system.

APPENDIX E. TYPICAL CODED DATA REPORTING FORMS

Figure	Title
	Environmental Monitoring Data Reporting Forms
E-1	Aerosol Run Report on Meteorology
E-2	UTSA-CART Wastewater Analysis Report
E-3	UTSA-CART Aerosol Run Analysis Report
	School Attendance Data Reporting Forms
E-4	Attendance Data Collection and Recording Form
E-5	Pupil Personnel Attendance Accounting Form 81-581-3200
E-6	Attendance Codes
E-7	Summary of Enrollment Data by School, Year and Quarter Year
E-8	Summary of Enrollment Data by School, Year, Quarter Year and Grade Level

AEROSOL RUN REPORT
Project 01-5082

Aerosol Run No. 1
Run Date 3-6-78

Run Times: Start 0956
Finish 1026

AEROSOL SAMPLERS

	Sampler #	Final Vol.	Label Code	Location	Operator
Upwind	208	200	1-Upwind-200		J. Paulk
	123				
Aeration basin 30m downwind	202	100	1-A30L-100		J. Harding
	216	100	1-A30R-100		
100m downwind	206	200	1-A100-200		R. Wyckoff
	223				
Surge basin 50 downwind	226	200	1-S50-200		J. Trevino
	211				

METEOROLOGICAL CONDITIONS

Actual Wind Direction	2m Tower	10m Tower
Just prior to run	70°	60°
0-15 min	60°	60°
10-20 min		
15-30 min	70°	65°
Wind Run (miles)	2.5	2.8
Wind Speed mph	5.0	5.6
Plant Wind Direction	70°	
Wind Speed	4 mph	

Temperature	Upwind	Downwind
dry bulb	51.2	51.2
wet bulb	47.0	47.0
Relative humidity	72	72

Solar Radiation
0.24 $\text{g/cal/cm}^2\text{/min}$

Clouds
Cover $^8/_8$
Type M7, L5
Min Ht. 12000-14000

Aeration Basin D.O. - 1.1 mg/L
Aeration Basin Flow - 14.0 MGD
Air Flow Totalizer Reading - 1441
Aeration Basin Water Temperature - 18°C

Field Supervisor HJH

Figure E-1. Aerosol Run Report on Meteorology

UTSA-CART WASTEWATER ANALYSIS REPORT 1 of 2

to SwRI on Project 01-5082, Portland

Date Reported 3-28-78

Sample Number	G-1 AB	G-1 SB	G-2 AB	G-2 SB
Bacteria				
SwRI Label Code	1-AER.B-1	1-SURGE-1	2-AER.B-1	2-SURGE-1
Total Coliform, cfu/100 ml	5.1×10^{7}	7.7×10^{3}	5.1×10^{7}	4.3×10^{3}
Mycobacteria, cfu/100 ml	2.4×10^{6}	1.1×10^{5}	2.1×10^{6}	2.5×10^{3}
Fecal Streptococci, cfu/100 ml	4.1×10^{5}	5.1×10^{2}	5.4×10^{5}	4.5×10^{2}
Pseudomonas, cfu/100 ml [α]	5.7×10^{4} (C)	3.7×10^{5}	7.3×10^{4} (C)	5.3×10^{4}
Coliphage				
SwRI Label Code	1-AER. B-1	1-SURGE-1	2-AER.B-1	2-SURGE-1
Total Count, pfu/l	3.8×10^{5}	6.0×10^{2}	9.6×10^{5}	8.0×10^{2}
Solids Fraction, pfu/l	2.2×10^{5}	NA	5.0×10^{5}	NA
Liquid Fraction, pfu/l	1.6×10^{5}	NA	4.6×10^{5}	NA
Efficiency, %	NA	NA	NA	NA
Viruses [β]				
SwRI Label Code	1-AER.B-1	1-SURGE-1	2-AER.B-1	2-SURGE-1
3-Day (HeLa):				
Total Count, pfu/l	7.8×10^{2}	2.9×10^{1}	4.9×10^{2}	< 0.05
Solids Fraction, pfu/l	7.6×10^{2}	NA	4.8×10^{2}	NA
Liquid Fraction, pfu/l	1.6×10^{1}	NA	8.6×10^{0}	NA
7-Day (BGM):				
Total Count, pfu/l	2.8×10^{2}	3.2×10^{0}	1.1×10^{2}	<0.05
Solids Fraction, pfu/l	2.6×10^{2}	NA	1.1×10^{2}	NA
Liquid Fraction, pfu/l	2.0×10^{1}	NA	1.3×10^{0}	NA
Efficiency, %	100	100	86	69

COMMENTS:

[α] (C) isolations on Cetrimide agar.

[β] Virus levels corrected for concentration efficiency as indicated.

Figure E-2. UTSA-CART Wastewater Analysis Report

1 of 1

UTSA-CART AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-5082, Portland

Date Reported 3-28-78

Run Number 1

Run Date 3-6-78

Aerosol Analysis:

Sampler	A-1-1	A-1-2	A-1-3	A-1-4	A-1-5
SwRI Label Code	1-UPWIND	1-A30R	1-A30L	1-A100	1-S50
Coliphage					
Coliphage Count, pfu/ml	<0.04(ND)	0.20	0.36	0.16	<0.04(ND)
Bacteria					
Total Coliform, cfu/100ml	$<2.0\times10^{0}$(ND)	8.5×10^{1}	1.4×10^{2}	1.4×10^{1}	$<2.0\times10^{0}$(N
Fecal Streptococci, cfu/100ml	$<2.0\times10^{0}$(ND)	3.3×10^{1}	4.0×10^{1}	4.0×10^{0}	$<2.0\times10^{0}$(N
Pseudomonas, cfu/100ml	$<3.3\times10^{2}$(ND)	3.0×10^{3}	$<3.3\times10^{2}$(ND)	2.5×10^{4}(CS)	4.2×10^{5}(C
Mycobacteria, cfu/100ml	$<2.5\times10^{0}$(ND)	2.8×10^{2}	2.4×10^{2}	$\sim2.5\times10^{1}$	1.3×10^{1}

COMMENTS:

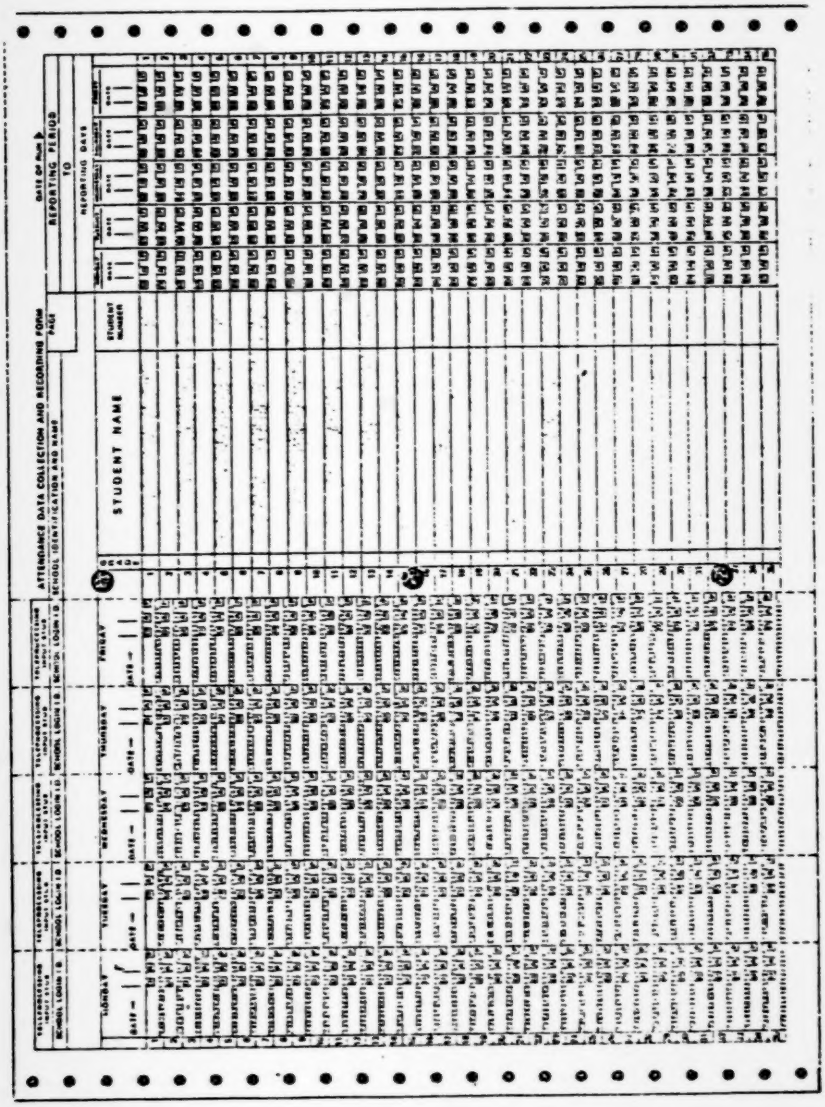
NOTATION:
TNTC - too numerous to count
ND - none detected
CS - contaminated sample

B. Moore Lab Director

Figure E-3. UTSA-CART Aerosol Run Analysis Report

ATTENDANCE

ATTENDANCE DATA COLLECTION AND RECORDING FORM:



ATTENDANCE DATA COLLECTION AND RECORDING FORM

SCHOOL IDENTIFICATION AND NAME

PAGE

DATE OF RUN

REPORTING PERIOD

TO

REPORTING DAYS

TELEPROCESSING INPUT STUB

SCHOOL LOGIN I.D.

MONDAY DATE –

TUESDAY DATE –

WEDNESDAY DATE –

THURSDAY DATE –

FRIDAY DATE –

STUDENT NAME

STUDENT NUMBER

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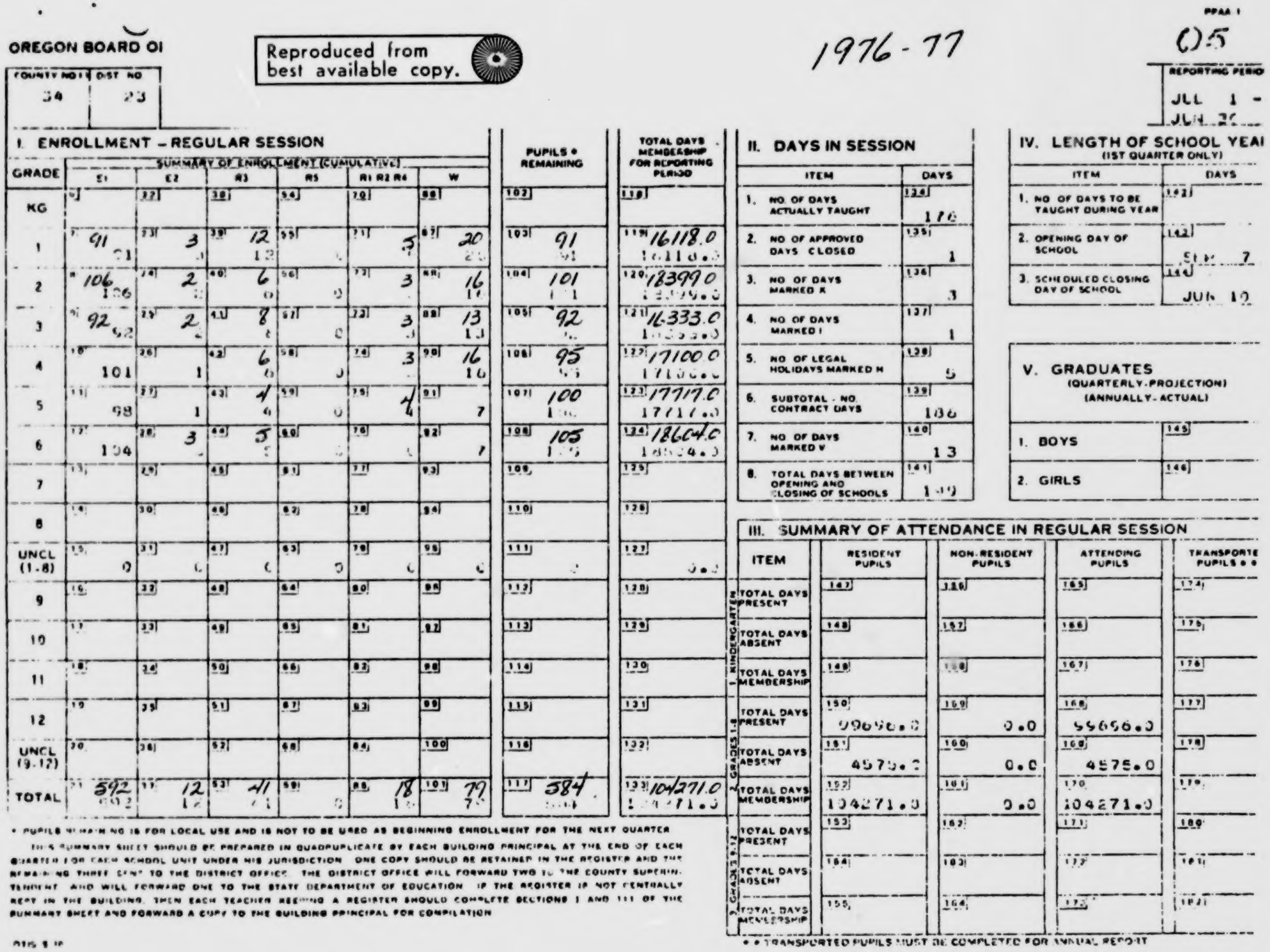
Figure E-4. Attendance Data Collection and Recording Form



OREGON BOARD OI

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1976-77

PPAA 1

05

COUNTY NO	DIST NO
34	23

REPORTING PERIO

JUL 1 -
JUN 30

I. ENROLLMENT – REGULAR SESSION

GRADE	SUMMARY OF ENROLLMENT (CUMULATIVE) E1	E2	R3	R5	R1 R2 R4	W	PUPILS * REMAINING	TOTAL DAYS MEMBERSHIP FOR REPORTING PERIOD
KG								
1	91 91	3	12 12		5	20	91 91	16118.0 16118.0
2	106 106	2	6 6	0	3	16 16	101 101	18399.0 18399.0
3	92 92	2	8	0	3	13 13	92	16333.0 16333.0
4	101	1	6 6	0	3	16 16	95	17100.0 17100.0
5	98	1	4 4	0	4	7	100	17717.0 17717.0
6	104	3	5			7	105	18604.0 18604.0
7								
8								
UNCL (1-8)	0	0	0	0	0	0	0	0.0
9								
10								
11								
12								
UNCL (9-12)								
TOTAL	592 592	12 12	41 41	0	18 18	79 79	584 584	104271.0 104271.0

* PUPILS REMAINING IS FOR LOCAL USE AND IS NOT TO BE USED AS BEGINNING ENROLLMENT FOR THE NEXT QUARTER

THIS SUMMARY SHEET SHOULD BE PREPARED IN QUADRUPLICATE BY EACH BUILDING PRINCIPAL AT THE END OF EACH QUARTER FOR EACH SCHOOL UNIT UNDER HIS JURISDICTION. ONE COPY SHOULD BE RETAINED IN THE REGISTER AND THE REMAINING THREE SENT TO THE DISTRICT OFFICE. THE DISTRICT OFFICE WILL FORWARD TWO TO THE COUNTY SUPERINTENDENT AND WILL FORWARD ONE TO THE STATE DEPARTMENT OF EDUCATION. IF THE REGISTER IS NOT CENTRALLY KEPT IN THE BUILDING, THEN EACH TEACHER KEEPING A REGISTER SHOULD COMPLETE SECTIONS I AND III OF THE SUMMARY SHEET AND FORWARD A COPY TO THE BUILDING PRINCIPAL FOR COMPILATION

OIS 8 IP

II. DAYS IN SESSION

ITEM	DAYS
1. NO. OF DAYS ACTUALLY TAUGHT	176
2. NO. OF APPROVED DAYS CLOSED	1
3. NO. OF DAYS MARKED X	3
4. NO. OF DAYS MARKED I	1
5. NO. OF LEGAL HOLIDAYS MARKED H	5
6. SUBTOTAL - NO. CONTRACT DAYS	186
7. NO. OF DAYS MARKED V	13
8. TOTAL DAYS BETWEEN OPENING AND CLOSING OF SCHOOLS	199

IV. LENGTH OF SCHOOL YEAR

(1ST QUARTER ONLY)

ITEM	DAYS
1. NO. OF DAYS TO BE TAUGHT DURING YEAR	
2. OPENING DAY OF SCHOOL	SEP 7
3. SCHEDULED CLOSING DAY OF SCHOOL	JUN 10

V. GRADUATES

(QUARTERLY-PROJECTION)
(ANNUALLY-ACTUAL)

1. BOYS	
2. GIRLS	

III. SUMMARY OF ATTENDANCE IN REGULAR SESSION

	ITEM	RESIDENT PUPILS	NON-RESIDENT PUPILS	ATTENDING PUPILS	TRANSPORTED PUPILS * *
KINDERGARTEN	TOTAL DAYS PRESENT				
	TOTAL DAYS ABSENT				
	TOTAL DAYS MEMBERSHIP				
GRADES 1-8	TOTAL DAYS PRESENT	99696.0	0.0	99696.0	
	TOTAL DAYS ABSENT	4575.0	0.0	4575.0	
	TOTAL DAYS MEMBERSHIP	104271.0	0.0	104271.0	
GRADES 9-12	TOTAL DAYS PRESENT				
	TOTAL DAYS ABSENT				
	TOTAL DAYS MEMBERSHIP				

* * TRANSPORTED PUPILS MUST BE COMPLETED FOR ANNUAL REPORT

Figure E-5. Pupil Personnel Attendance Accounting Form 81-581-3200

Attendance Codes

E1 - Original entry - not previously enrolled during current school year in U.S.

E2 - Original entry - previously enrolled during current school year in state other than Oregon.

R1 - Received from another room, same school.

R2 - Received from another public school, same district.

R3 - Received from public school in state but outside local district.

R4 - Re-entering after withdrawal or discharge.

R5 - Received from non-public school in state.

W1 - Promoted or transferred to another classroom, same bldg.

W2 - Promoted or transferred to another public school, same district.

W3 - Promoted or transferred to another non-public school, same district.

W4 - Moved out of local district or state.

W5 - Quit school. Beyond compulsory school age.

W6 - Issued work permit.

W7 - Graduated.

W8 - Withdrawn. Other reasons.

Figure E.6. Attendance Codes

ENROLLMENT SUMMARY FOR DURHAM

	PRESENT	ABSENT	MEMBERSHIP
1969-70			
Q1	2004	73	2077
Q2	5130	222	5351
Q3	5546	263	5809
Q4	4683	271	4954
1970-71			
Q1	1909	42	1951
Q2	6130	348	6477
Q3	5581	413	5994
Q4	5232	256	5487
1971-72			
Q1	2014	72	2086
Q2	6177	279	6456
Q3	6462	566	7028
Q4	5580	303	5882
1972-73			
Q1	2061	68	2129
Q2	5520	303	5823
Q3	5810	536	6346
Q4	4996	355	5351
1973-74			
Q1	2485	98	2582
Q2	6984	518	7502
Q3	6831	369	7200
Q4	5759	279	6038
1974-75			
Q1	1998	47	2044
Q2	5359	304	5663
Q3	5240	262	5501
Q4	4849	276	5124
1975-76			
Q1	2580	83	2662
Q2	6501	308	6810
Q3	6717	605	7322
Q4	6439	362	6800
1976-77			
Q1	2409	69	2477
Q2	6702	371	7073
Q3	6147	299	6446
Q4	5992	271	6263
1977-78			
Q1	2172	69	2240
Q2	6223	329	6552
Q3	6470	353	6823
Q4	5621	282	5902

Figure E-7. Summary of Enrollment Data by School, Year and Quarter Year

1971-72 School Year

Tualatin

Quarter 1

	Mbr.	Ab.	Pres.
K	---	---	---
1	612.0	9.0	630.0
2	714.0	10.5	703.5
3	817.0	14.5	802.5
4	750.0	11.0	739.0
5	962.0	11.0	951.0
6	819.0	11.0	808.0

Quarter 2

	Mbr.	Ab.	Pres.
K	---	---	---
1	1944.0	123.0	1821.0
2	2184.0	116.0	2068.0
3	2551.0	102.5	2448.5
4	2461.0	125.5	2335.5
5	3020.0	104.5	2915.5
6	2623.0	88.5	2534.5

Quarter 3

	Mbr.	Ab.	Pres.
K	---	---	---
1	2066.0	164.0	1902.0
2	2245.0	202.0	2043.0
3	2641.0	179.0	2462.0
4	2696.0	144.5	2551.5
5	3055.0	252.5	2802.5
6	2801.0	113.0	2688.0

Quarter 4

	Mbr.	Ab.	Pres.
K	---	---	---
1	1774.0	113.0	1661.0
2	1820.0	105.5	1714.5
3	2200.0	123.0	2077.0
4	2261.0	141.0	2120.0
5	2640.0	122.0	2518.0
6	2352.0	72.0	2280.0

Figure E-8. Summary of Enrollment Data by School, Year, Quarter Year and Grade Level

APPENDIX F

AEROSOL SAMPLING RUN LAYOUTS

Figure	Title
F-1.	Aerosol Run No. 1
F-2.	Aerosol Run No. 2
F-3.	Aerosol Run No. 3
F-4.	Aerosol Run No. 4
F-5.	Aerosol Run No. 5
F-6.	Aerosol Run No. 6
F-7.	Enterovirus Aerosol Run No. 7

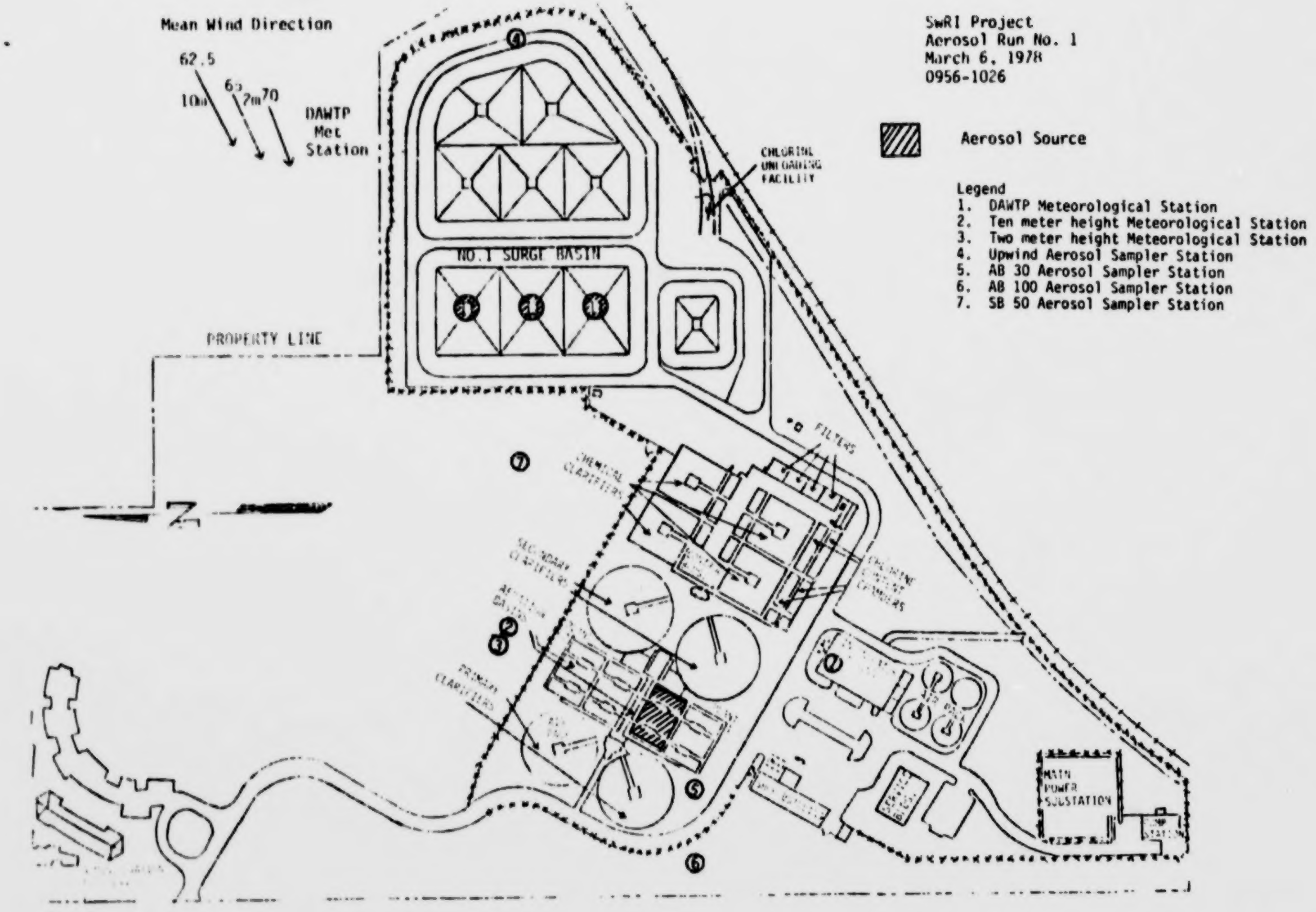


Figure F-1. Aerosol Run No. 1.

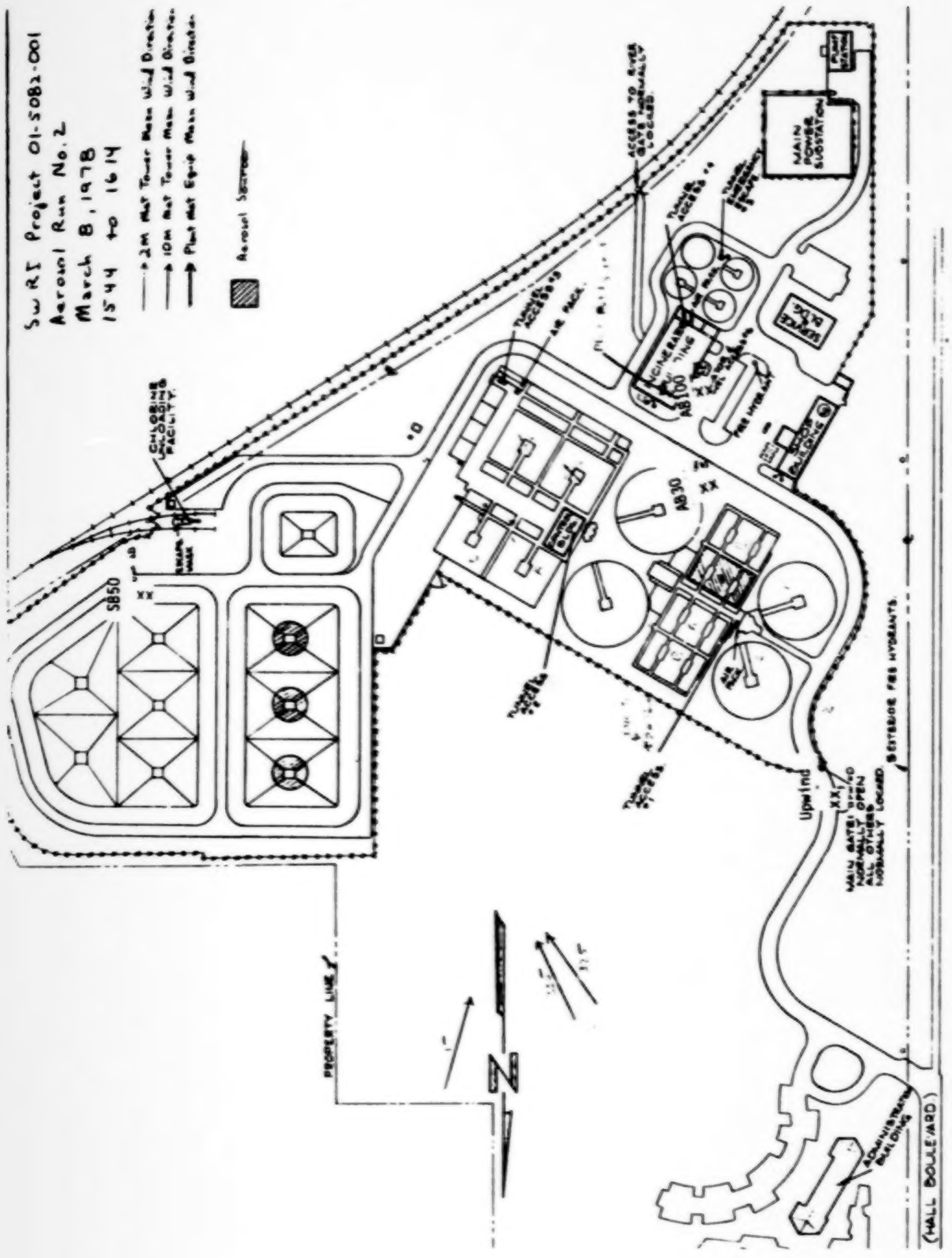
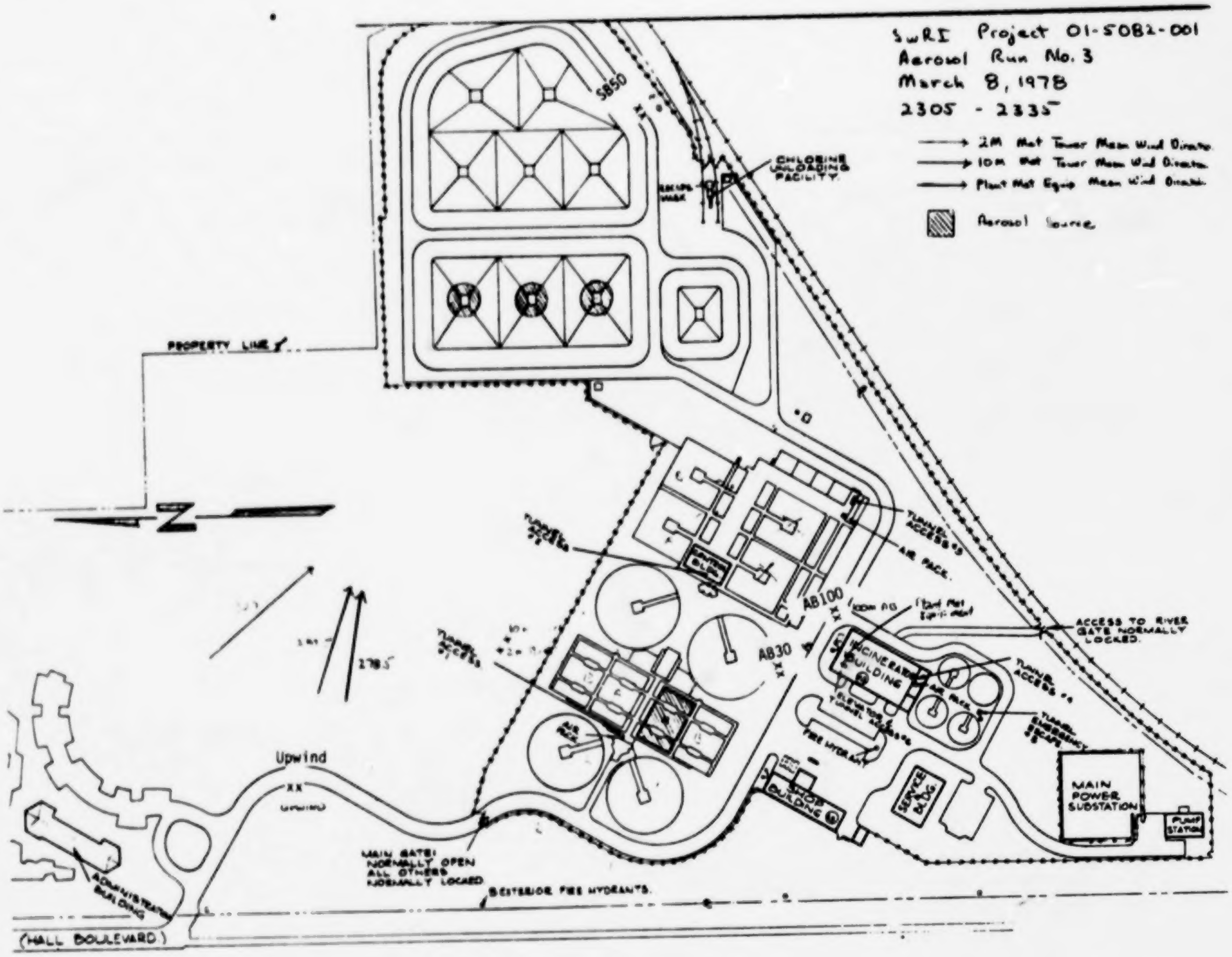


Figure F-2. Aerosol Run No.2



SwRI Project 01-5082-001
Aerosol Run No. 3
March 8, 1978
2305 - 2335

Figure F-3. Aerosol Run No. 3.

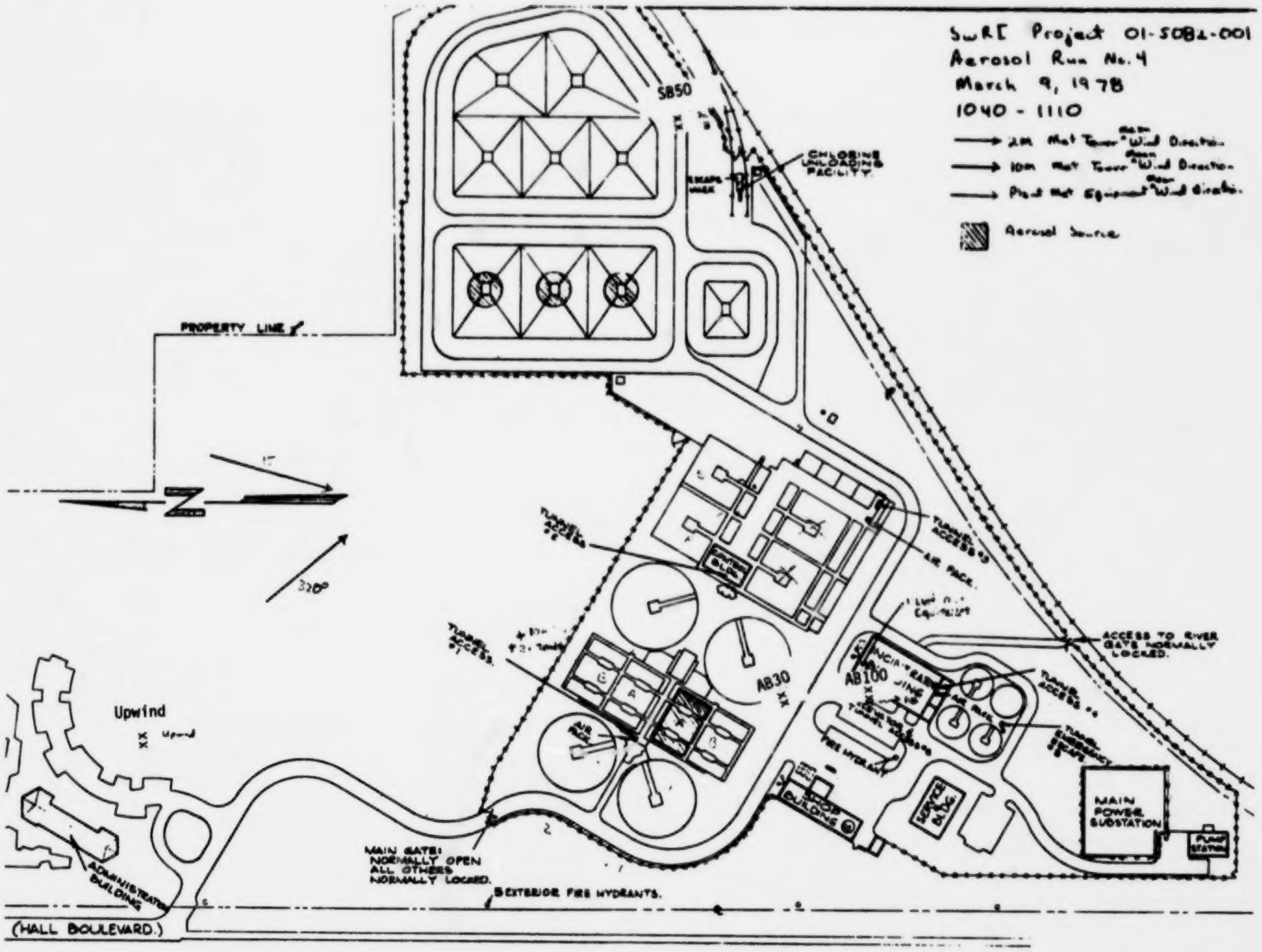


Figure F-4. Aerosol Run No. 4.

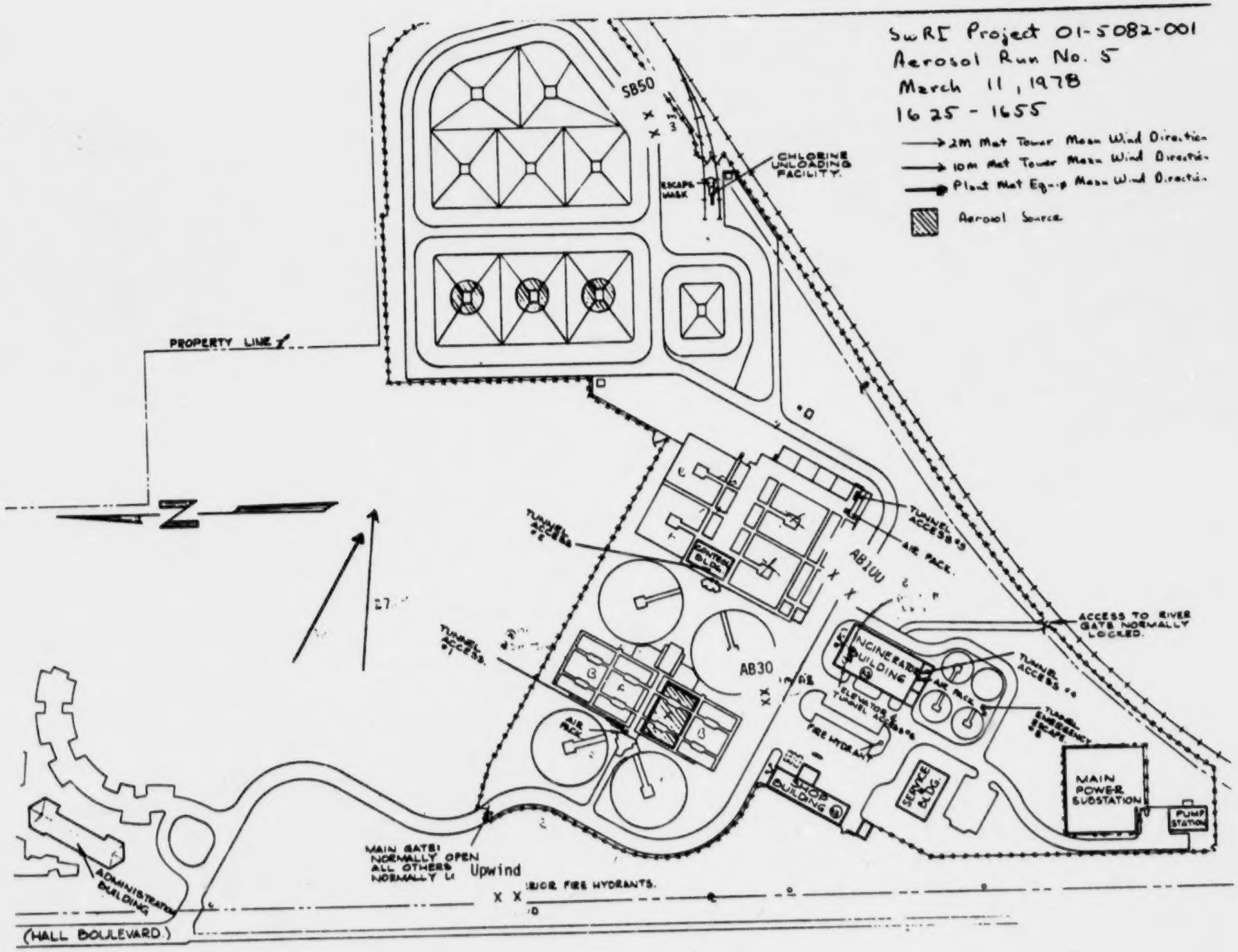


Figure F-5. Aerosol Run No. 5.

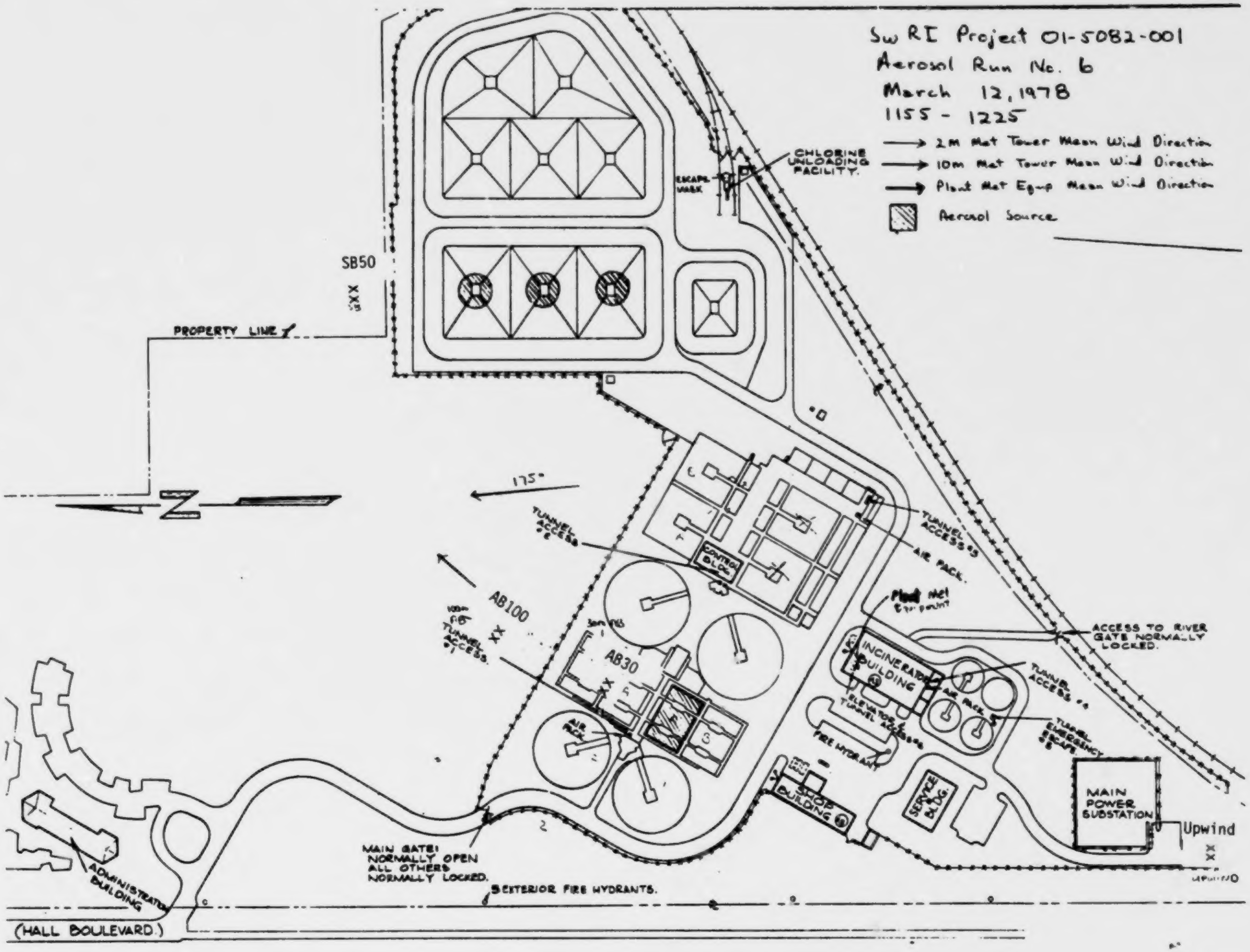


Figure F-6. Aerosol Run No. 6.

SwRI Project 01-5082-001
Virus Run
March 12, 1978
1415 - 2003

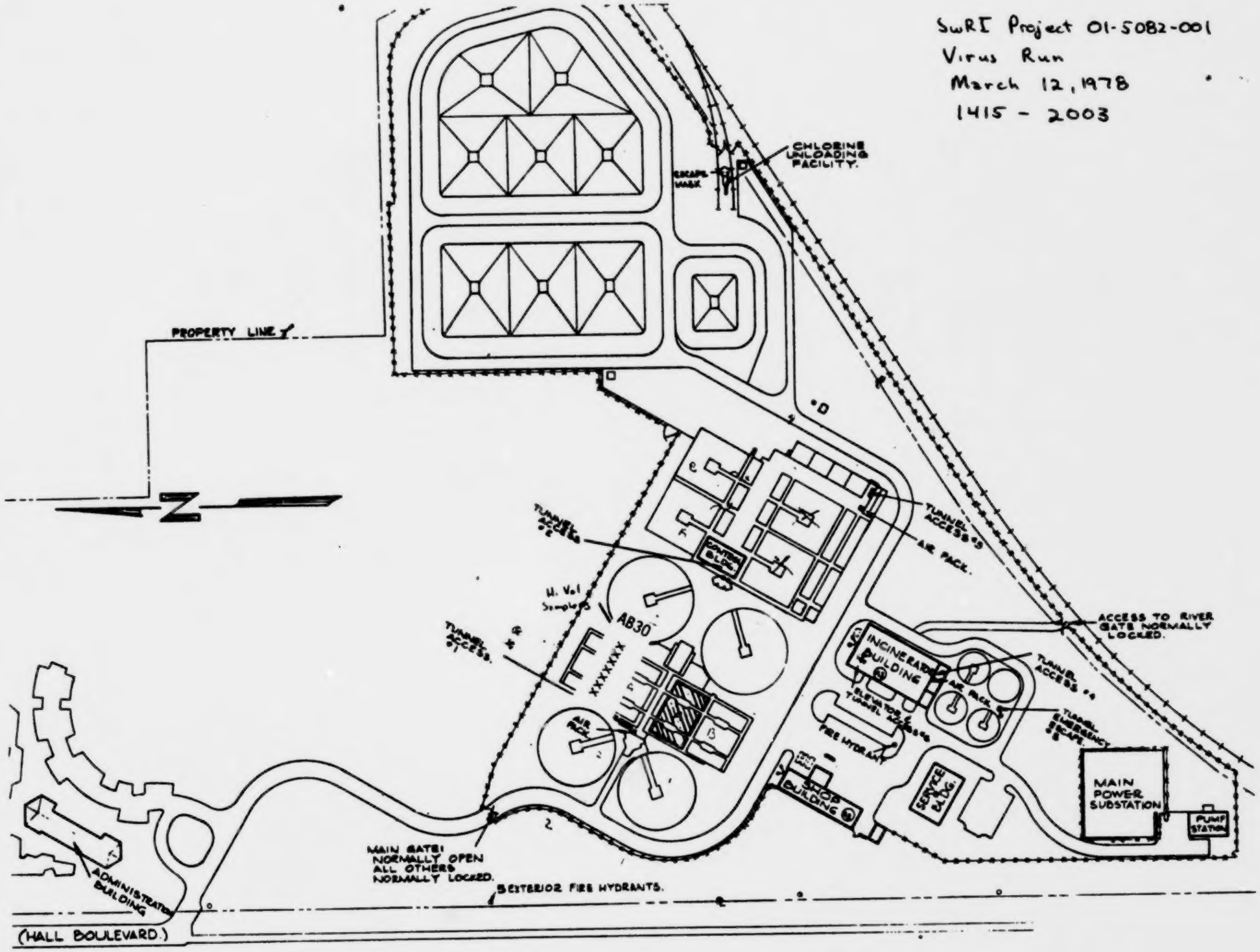


Figure F-7. Enterovirus Aerosol Run No. 7.

APPENDIX G

CLASS COHORT TIME SERIES PLOTS

Figure	Title
G-1	Quarterly Cohort Attendance (Entered Sixth Grade in 1971-72)
G-2	Quarterly Cohort Attendance (Entered Fifth Grade in 1971-72)
G-3	Quarterly Cohort Attendance (Entered Fourth Grade in 1971-72)
G-4	Quarterly Cohort Attendance (Entered Third Grade in 1971-72)
G-5	Quarterly Cohort Attendance (Entered Second Grade in 1971-72)
G-6	Quarterly Cohort Attendance (Entered First Grade in 1971-72)
G-7	Quarterly Cohort Attendance (Entered First Grade in 1972-73)
G-8	Quarterly Cohort Attendance (Entered First Grade in 1973-74)
G-9	Quarterly Cohort Attendance (Entered First Grade in 1974-75)
G-10	Quarterly Cohort Attendance (Entered First Grade in 1975-76)
G-11	Quarterly Cohort Attendance (Entered First Grade in 1976-77)
G-12	Quarterly Cohort Attendance (Entered First Grade in 1977-78)

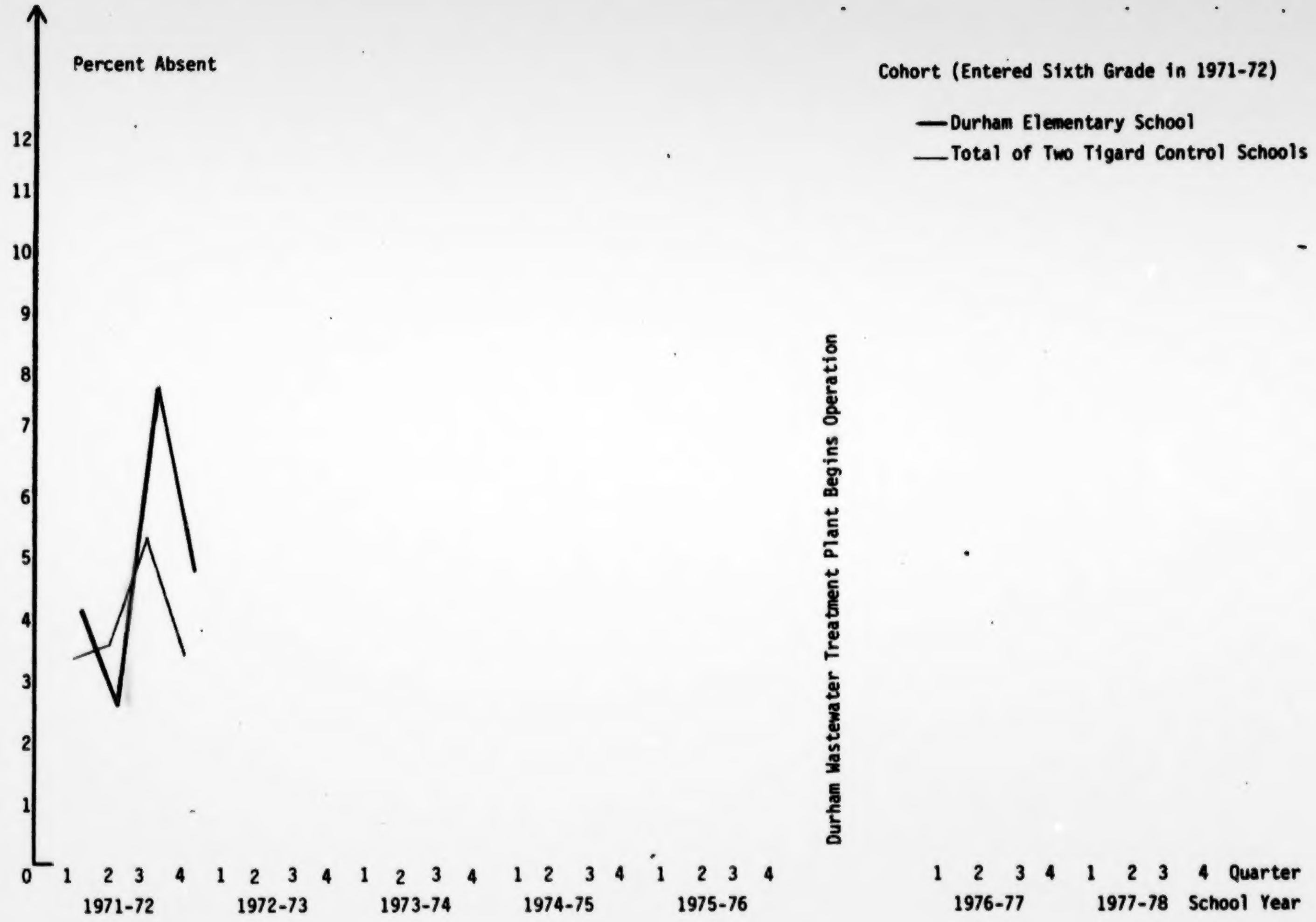


Figure G-1. Quarterly Cohort Attendance (Entered Sixth Grade in 1971-72).

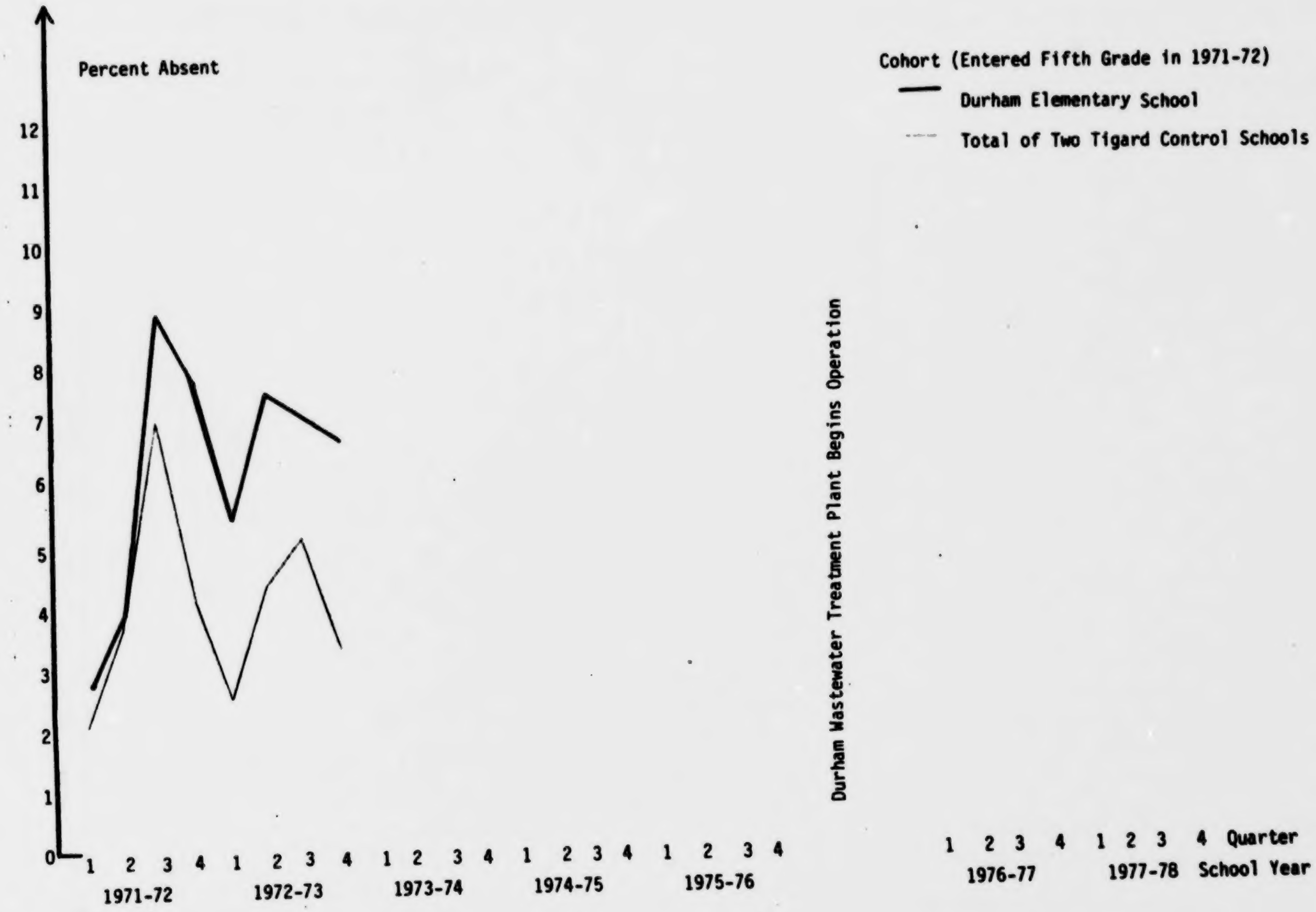


Figure G-2. Quarterly Cohort Attendance (Entered Fifth Grade in 1971-72).

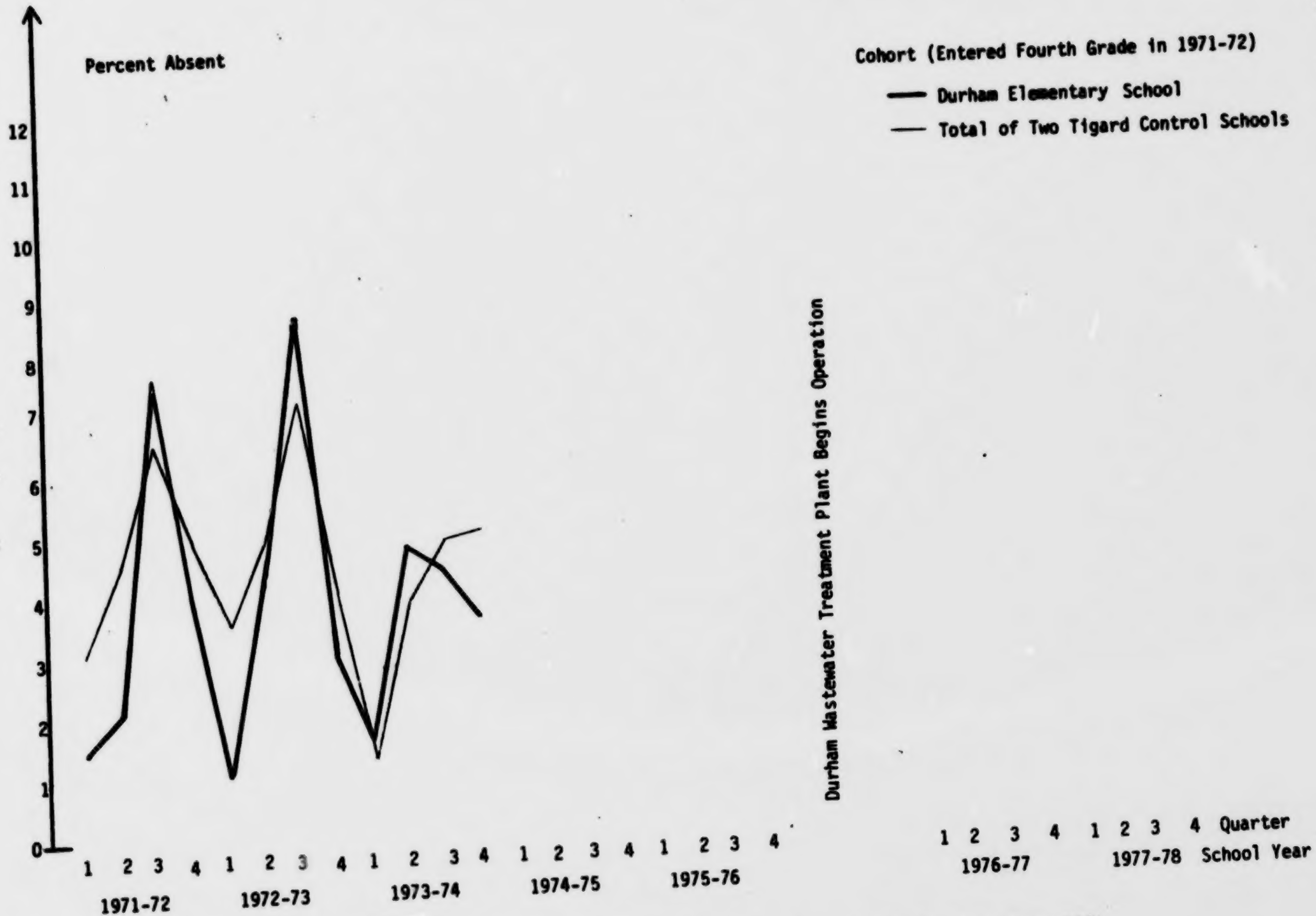


Figure G-3. Quarterly Cohort Attendance (Entered Fourth Grade in 1971-72).

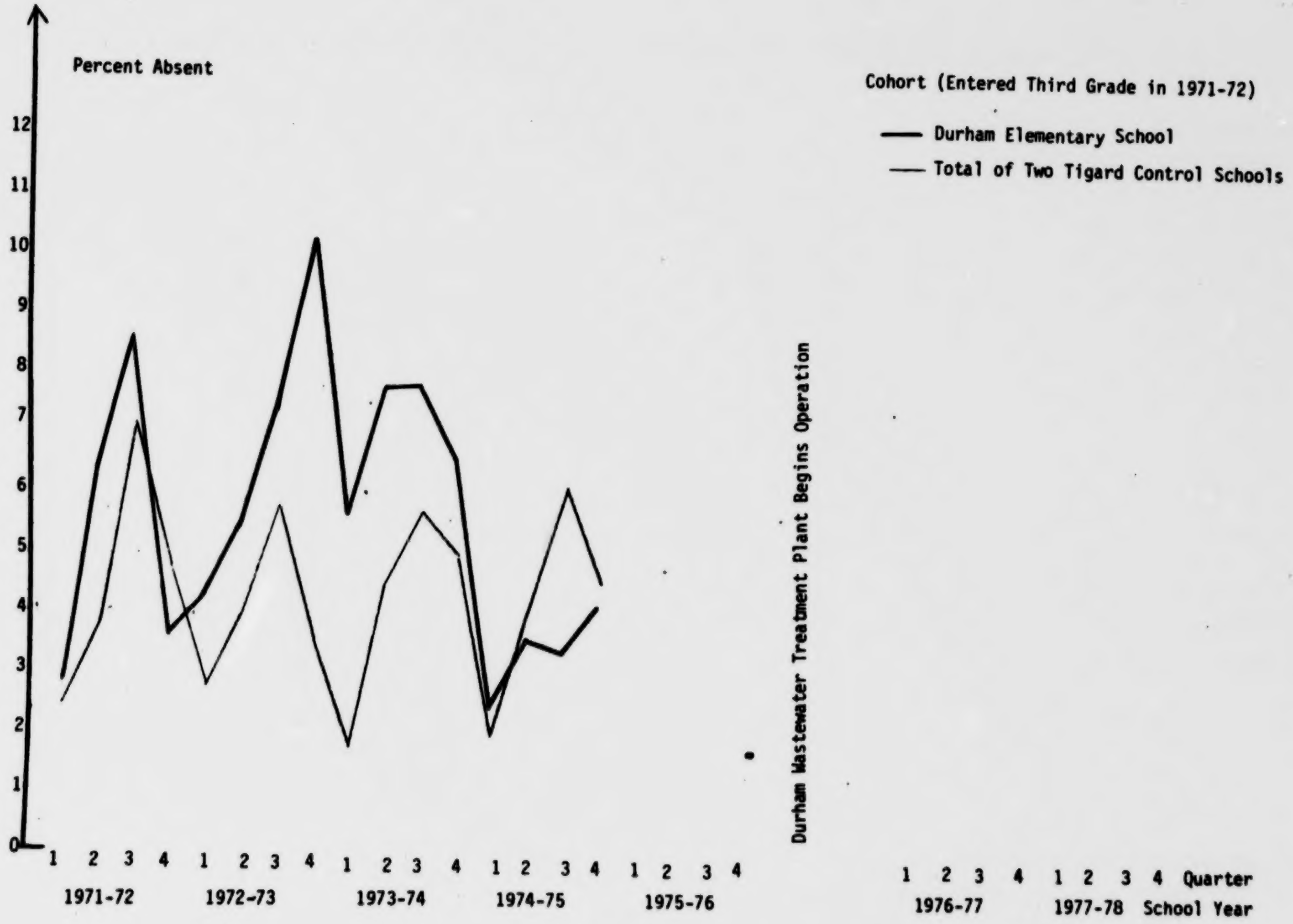


Figure G-4. Quarterly Cohort Attendance (Entered Third Grade in 1971-72).

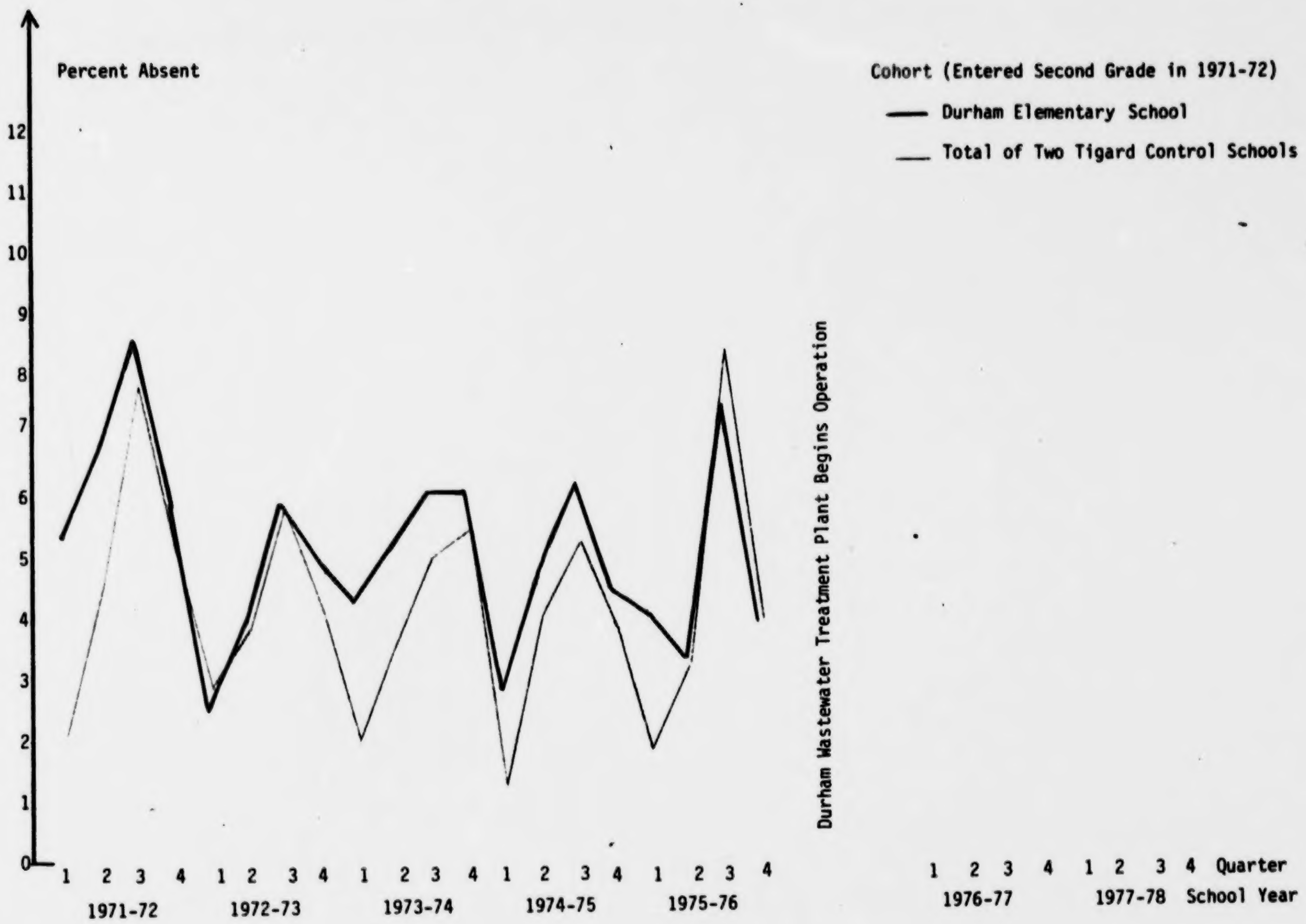


Figure G-5. Quarterly Cohort Attendance (Entered Second Grade in 1971-72).

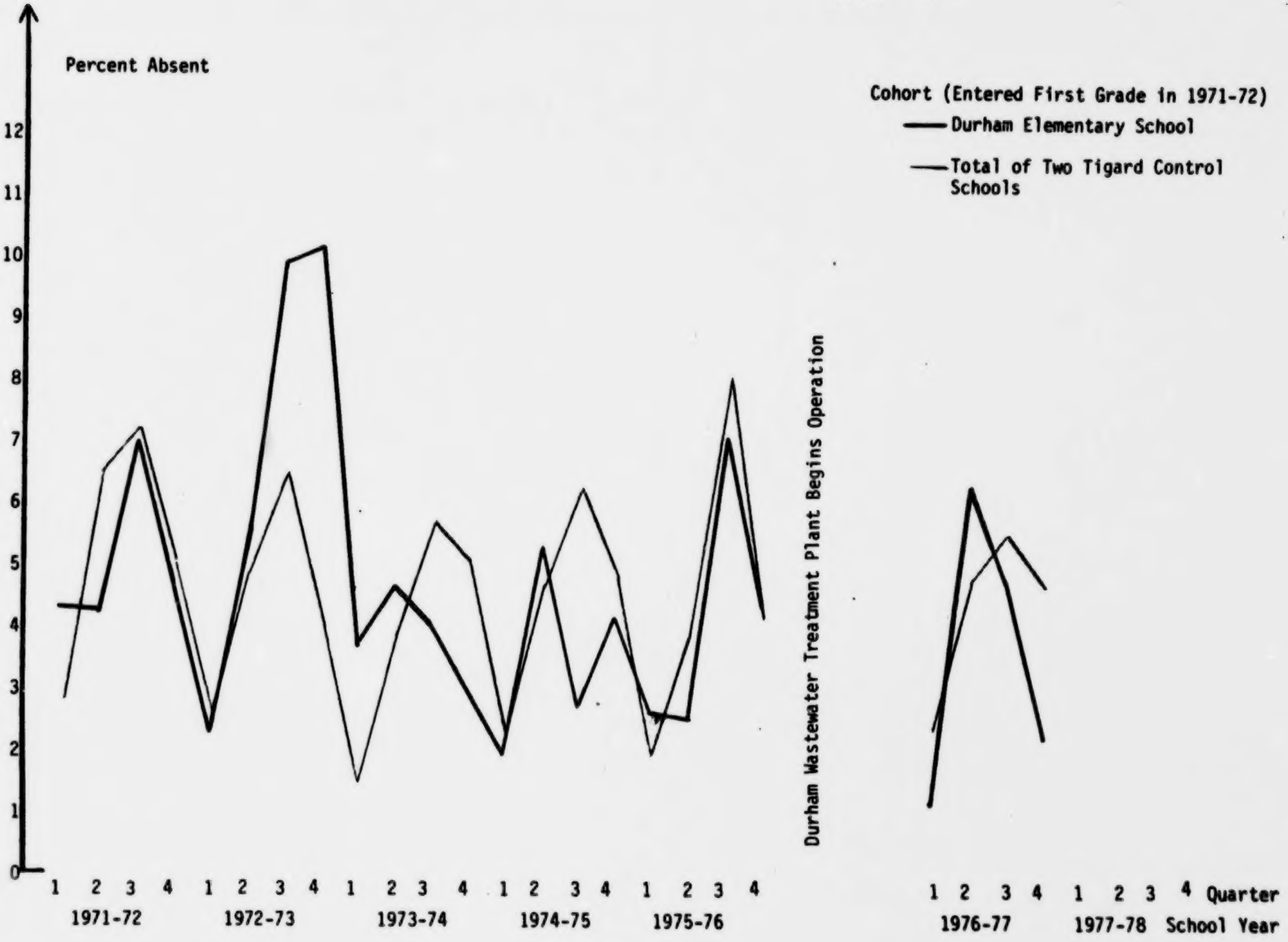


Figure G-6. Quarterly Cohort Attendance (Entered First Grade in 1971-72).

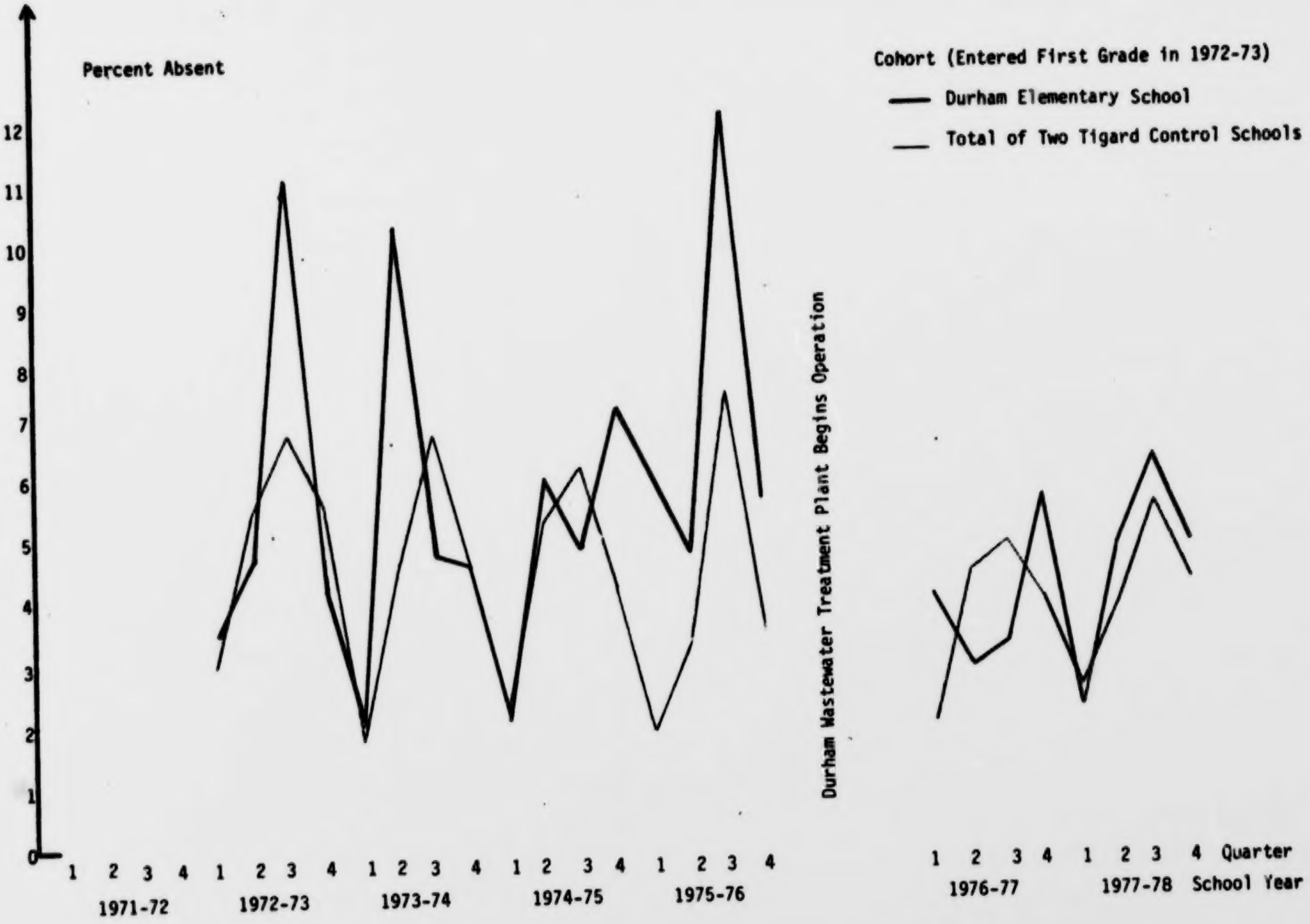


Figure G-7. Quarterly Cohort Attendance (Entered First Grade in 1972-73).

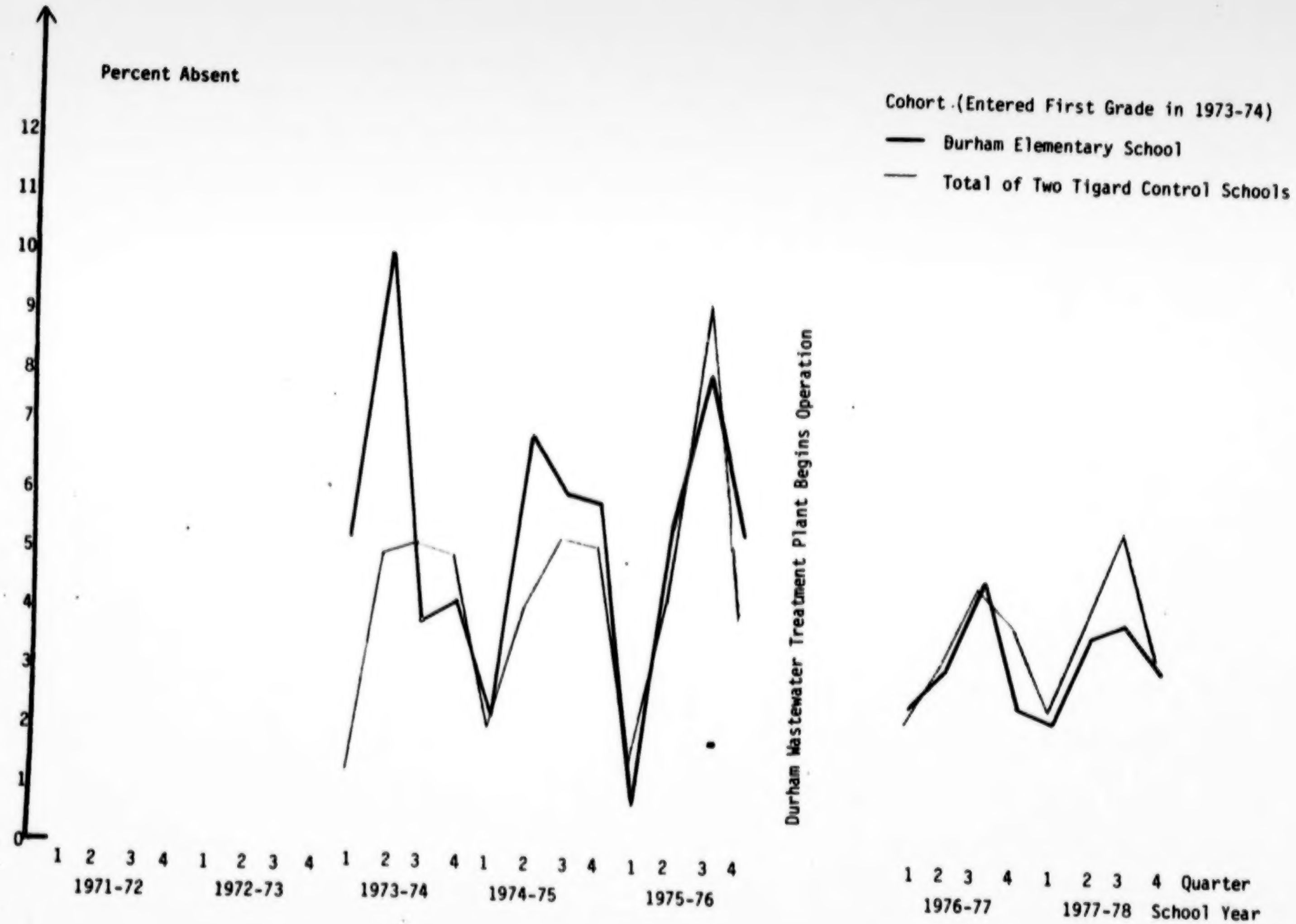


Figure G-8. Quarterly Cohort Attendance (Entered First Grade in 1973-74).

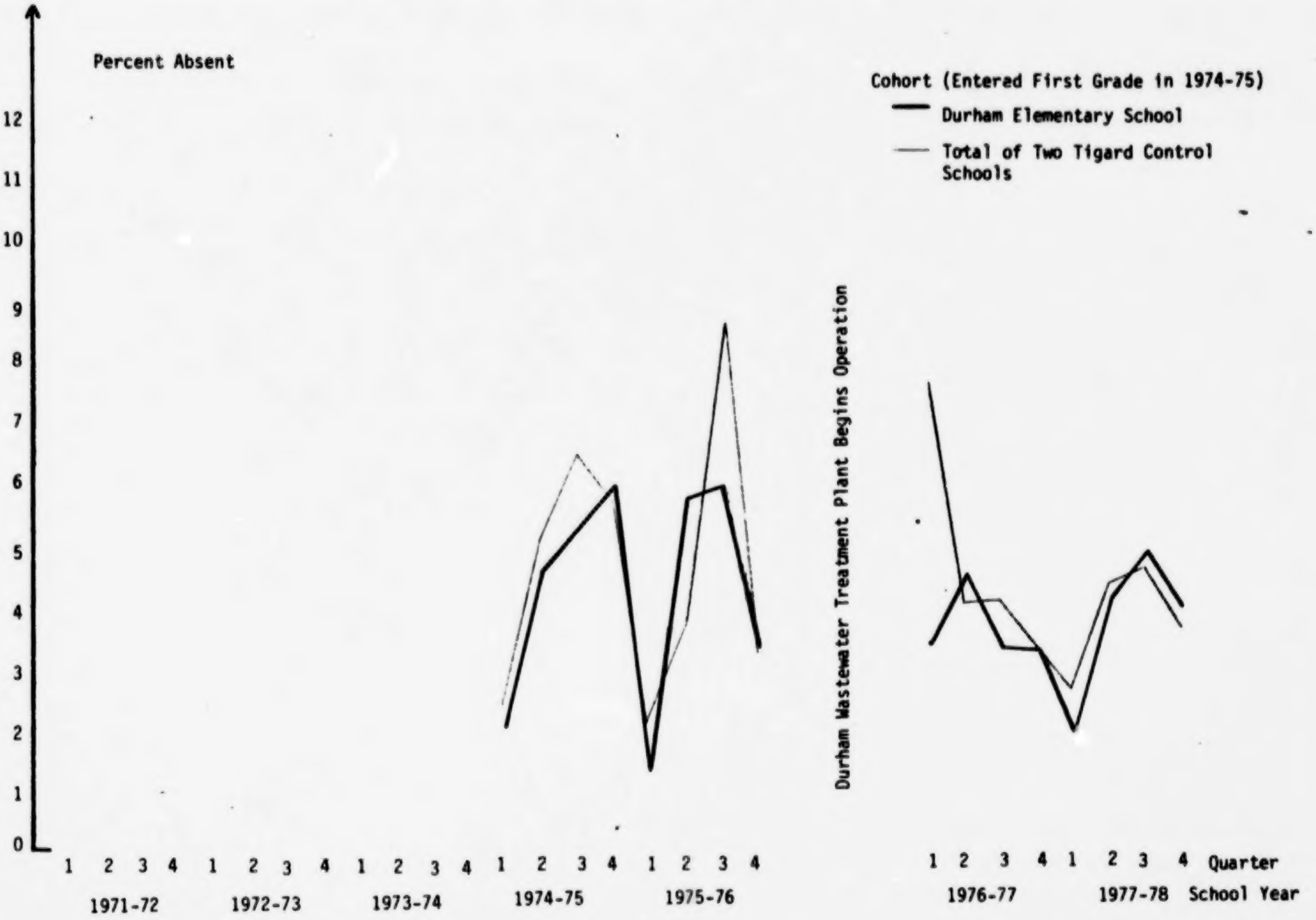


Figure G-9. Quarterly Cohort Attendance (Entered First Grade in 1974-75).

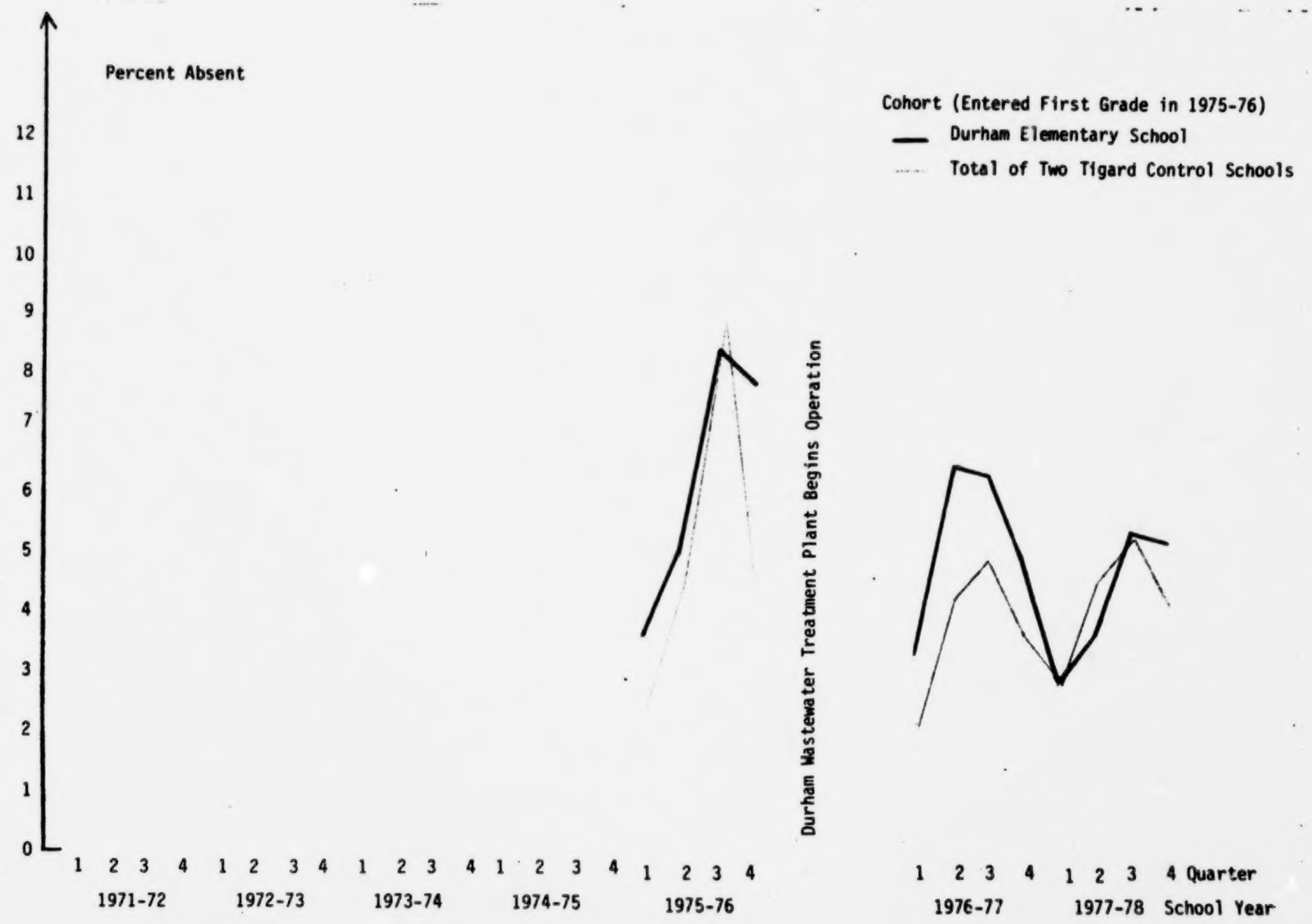


Figure G-10. Quarterly Cohort Attendance (Entered First Grade in 1975-76).

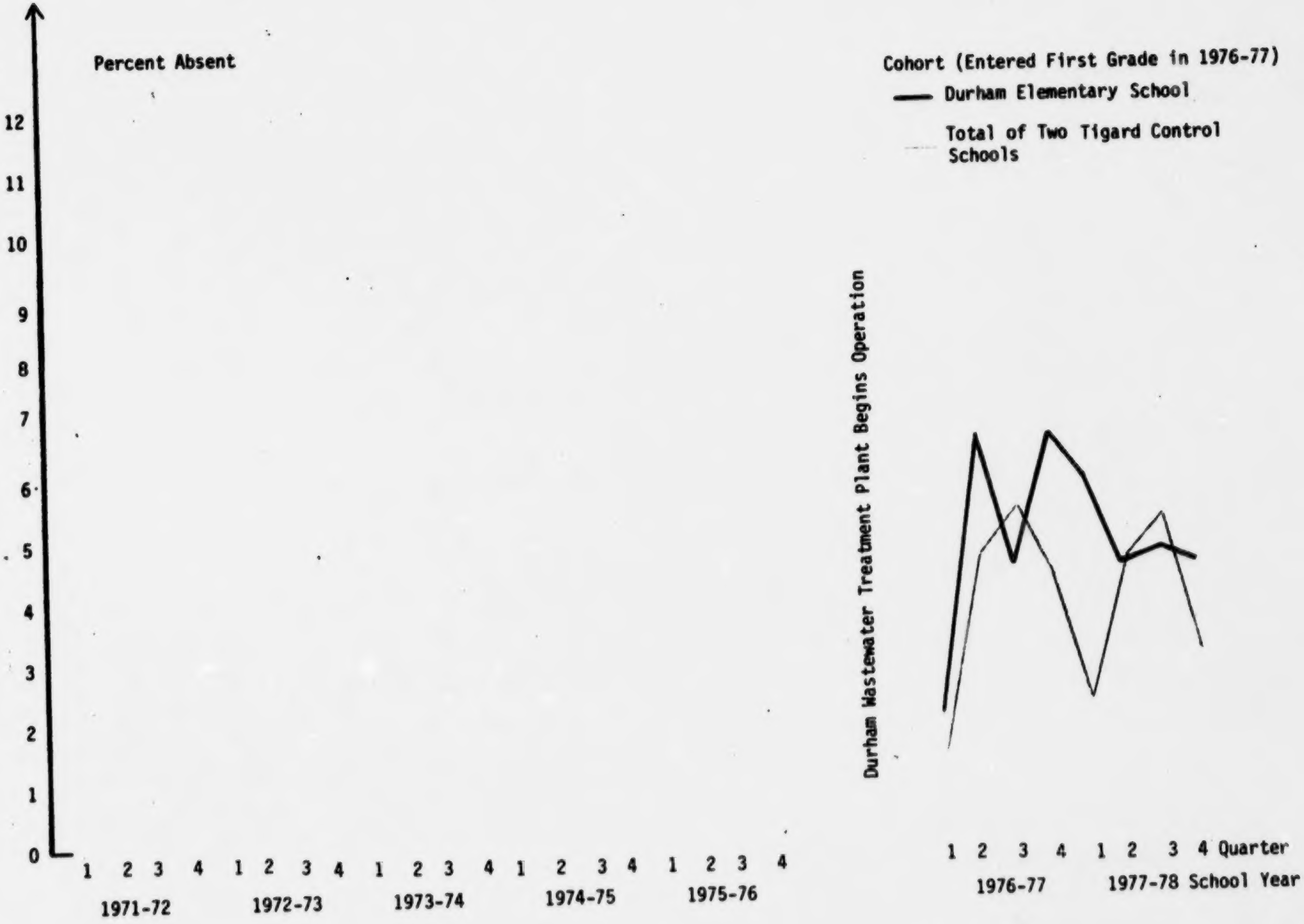


Figure G-11. Quarterly Cohort Attendance (Entered First Grade in 1976-77).

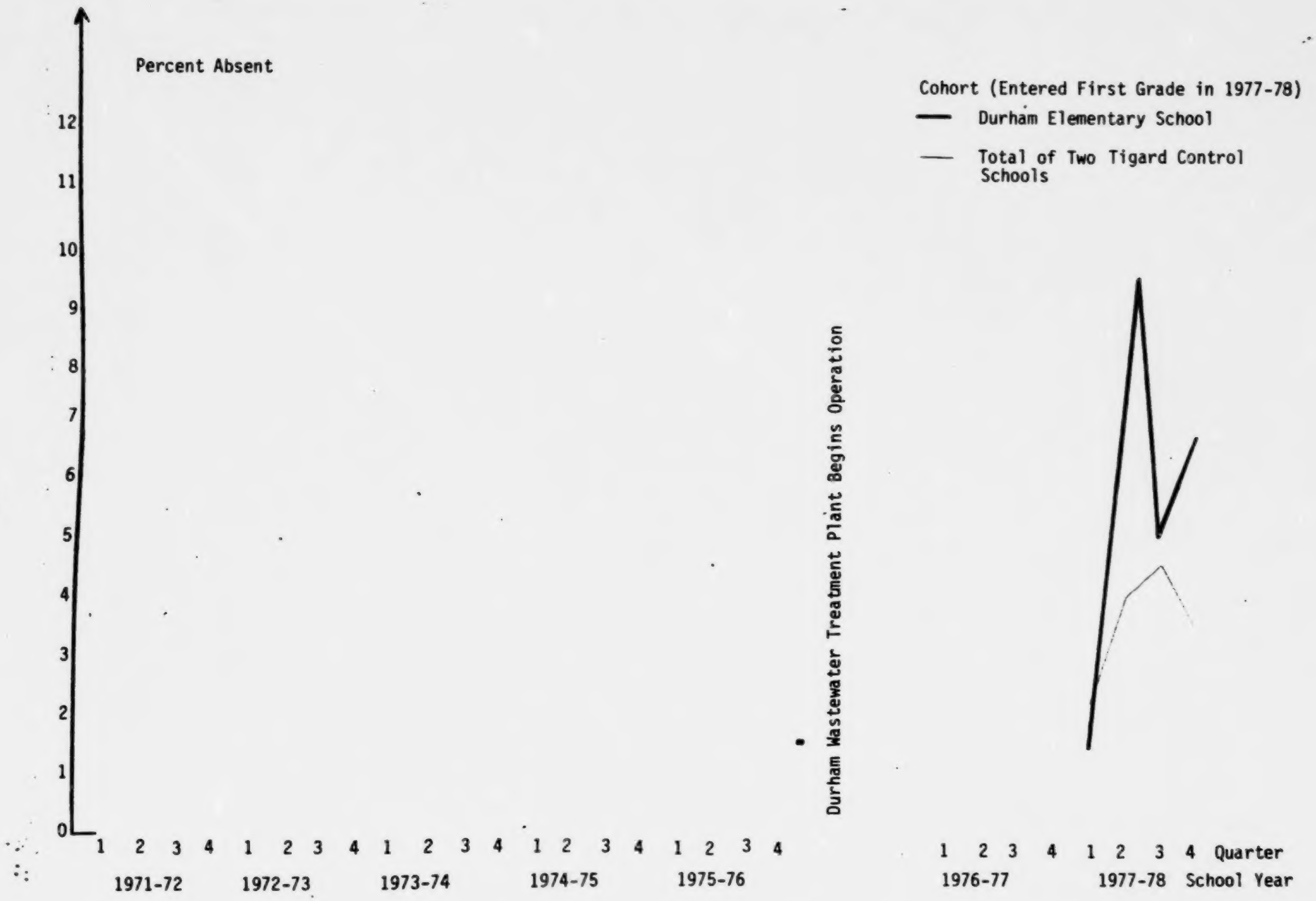


Figure G-12. Quarterly Cohort Attendance (Entered First Grade in 1977-78).